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ELECTRO-DIAGNOSIS

DISABILITIES OF THE LOCO-MOTOR APPARATUS FROM WOUNDS

MENTAL DISORDERS

WOUNDS OF THE PLEURA AND OF THE LUNG

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MEDICAL AND SURGICAL THERAPY

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VOLUME VI

ELECTRO-DIAGNOSIS AND LUNG WOUNDS MENTAL AND LOCOMOTOR DISABILITIES

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ELECTRO-DIAGNOSIS
AND
LUNG WOUNDS
MENTAL
AND
LOCOMOTOR DISABILITIES

ELECTRO-DIAGNOSIS

MENTAL DISORDERS

DISABILITIES OF THE LOCOMOTOR APPARATUS

WOUNDS OF THE PLEURA AND OF THE LUNG

BY

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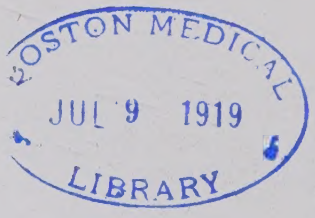

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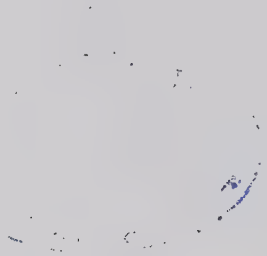
SECTION I

ELECTRO-DIAGNOSIS



ELECTRO-DIAGNOSIS

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CHAPTER I

THE TECHNIQUE OF ELECTRO-DIAGNOSIS

I. Definition

Electro-diagnosis may be defined as the summation of the results which can assist the clinician by determining the mode of reaction of the organism to different forms of electrical current.

The term more particularly suggests a process of exploration, based on the responses of motor nerves and muscles to electrical stimulation. Making an electro-diagnosis signifies, as a matter of fact, an investigation made to ascertain whether, in a patient suffering from some affection of the neuro-muscular system, the electrical reactions of the muscles and motor nerves differ from the normal physiological reactions, and if so, an examination of the nature of the difference.

It is not, however, merely for motor nerves that electrical investigation can afford evidence of clinical

value. Sensory nerves may also, in affections which involve them directly or indirectly, present alterations of excitability, into which it will sometimes be of interest to inquire. Similarly with certain reflex phenomena, among which is that known as voltaic vertigo, anomalies of which may reveal even slight disturbances of the mechanisms which govern them.

II. Apparatus Required

The apparatus necessary for electro-diagnosis comprises :

1. A faradic apparatus.
2. A galvanic apparatus.
3. Electrodes for application of currents, and conducting wires.

Some electrologists prefer to use condensers of different capacities in the place of galvanic and faradic apparatus.

Faradic Apparatus.—We shall presuppose a knowledge of the theory and structure of medical induction coils, with their primary and secondary windings, their interrupters, condensers, etc.

The commonest are sledge coils (fig. 1), in which the secondary can be made to approach and cover the primary coil to any desired extent. Some forms of this apparatus are intended to remain fixed on the operator's table, others are portable. They are supplied from accumulators, two or three Leclanché cells, or two dry cells.

In order to standardise the results of electrical examination, it is desirable that all faradic apparatus should be supplied with a current of *fixed voltage* (4 volts, for instance). Similarly, there should be an agreement between instrument-makers whereby the *resistance* (measured in ohms) of the two secondary coils which they manufacture (coarse and fine winding) should be *constant*.[1] It is useful to have an interrupter.

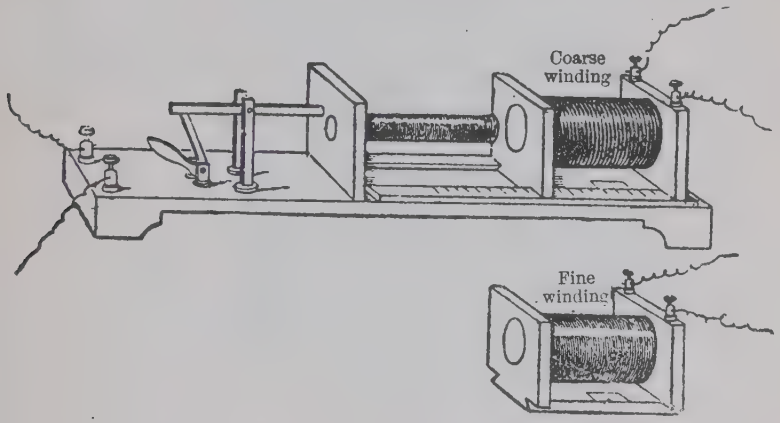


FIG. 1.—Faradic sledge coil.

with which a tetanising current can be produced, as well as a single-wave current. One of the most useful types of apparatus from this point of view is the lever interrupter, which will give any frequency of interruption from 50 to 3,000 per minute.

The intensity of the faradic current is increased by approximating the secondary and primary coils,

[1] The secondary coils of the present instruments have the resistance of 1 to 10 ohms in the coil with coarse wire, and 500 to 1 000 ohms in the coil with fine wire.

and for clinical purposes it is considered sufficient to measure this intensity in terms of the distance (in centimetres) between the two coils.[1]

Galvanic Apparatus.—If the continuous current of an electric-light circuit is to be utilised, a *reducer of potential* will afford a suitable current at its distal terminals. A *rheostat* is sometimes used, instead of a potential-reducer, to graduate the current.

Rheostats are of the solid or "liquid" type. They are introduced into the circuit as an additional resistance, variable at will. As with the potential-reducer, the graduation of the current is smooth.

Urban electric-supply systems, producing electric energy by continuous current dynamos, in reality supply an undulatory current which is equivalent, for practical purposes, to a continuous current. The frequency of the undulation is usually so great and the waves so small that it produces no appreciable effect in the stimulation of nerves and muscles. At the same time it is always preferable to use a source of absolutely pure and unvarying continuous current. The best source, from this point of view, is a *battery of accumulators* (30 to 40 cells).

Since accumulators require attention and recharging, a *cell-battery* is sometimes preferred. These should be of sufficient capacity to ensure a satisfactory supply. Cells of the Leclanché type, using am-

[1] Instruments for measuring the faradic current in units of electricity have not yet been used in practice; this is to be regretted, since, with many varieties of apparatus, results obtained by different observers cannot be compared.

monium or zinc chloride, and without the porous pot, are the most popular.

No forms of the above-described apparatus are portable. Hence manufacturers have produced *portable cell-batteries*, in the usual model of which mercury bisulphate is the liquid element (fig. 2). A

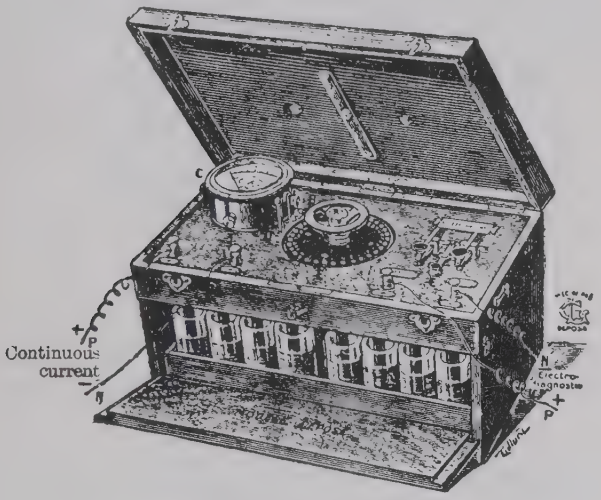


Fig. 2.—Portable galvanic battery.

current of sufficient intensity for all the present needs of electro-diagnosis is ensured with 30 to 40 cells.

Most portable batteries are fitted with an unsatisfactory appliance for graduation, the collector. A collecting arm, by passing over a series of "buttons," introduces the cells successively into the circuit. Shifting from one button to the next causes a sudden rise in E.M.F. equivalent to the voltage of the corresponding cell; this is a disadvantage in investigating quantitative changes of excitability.

one, however, which may easily be corrected by the introduction of a rheostat.

The intensity of a continuous current is measured by means of the milliamperemeter. This, to be read easily, should be *aperiodic*; that is to say, the indicating needle should come immediately to rest in the correct position without any periodic oscillation.

Permanent and Varying States. Simple and Double Key.—In the continuous current, the *permanent* state and the *varying states* are distinguished. The

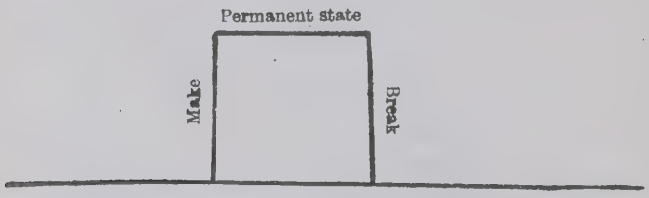


FIG. 3.—Permanent state of the constant current, and the varying states, at make and at break.

current is said to pass into a permanent state when its intensity does not vary as time passes. By varying states during "make" and "break," we understand the periods while the current is being made and being broken, and, more particularly, *rapid* make and *rapid* break (fig. 3).

The varying states of make and break, known also as make and break waves, induce muscular contractions when the current intensity is sufficient. To produce these contractions in a convenient way, an interrupter, such as the Morse key (the key of telegraphic transmitters), also known as the "simple" key, is introduced into the circuit. When the key is

depressed the circuit is suddenly made; when it is released it springs back, and the circuit is broken.

The interrupter is sometimes fixed on the handle of the exploring electrode (interrupter handle).

To enable the polarity of the electrodes to be reversed easily, a current reverser is introduced into the circuit, in front of the Morse key. The functions, however, of reverser and interrupter are excellently

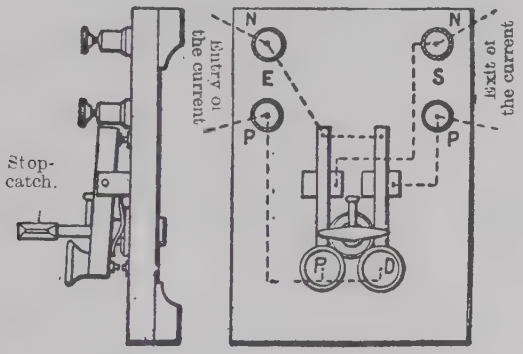


FIG. 4.—Courtade's key.

combined, from the practical point of view, in the "double key."

Courtade's "interrupter-reverser," or "Courtade's key" (fig. 4), consists of a double key, each extremity of which can make contact with two studs—anterior and posterior. The anterior studs represent the bifurcated extremity of one conducting wire from the battery, the posterior the bifurcated extremity of the wire from the other pole of the battery.

The wires to the electrodes are attached to the pivots of the keys.

The position of the keys in fig. 5 is that of rest. It will be seen that when both keys are *raised*, no current is conducted. But if the key A (fig. 6) is lowered, its posterior extremity breaks contact with the posterior stud, and its anterior makes contact with the anterior stud; in this way the circuit is made. By following out the wire connections in the diagram it will be seen that the

negative pole of the battery is then in connection with the active electrode; this is therefore a *negative make* (fig. 6). When contact

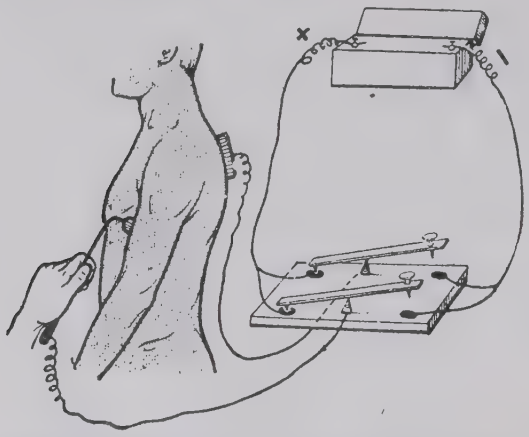


FIG. 5.—Manipulation of the double key (position of rest).

is broken at A, *i.e.* when the key A returns to the position of rest, the circuit is broken, and thus a *negative break* has been produced.

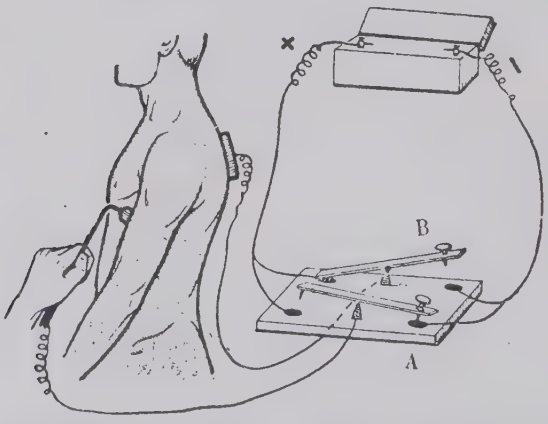


FIG. 6.—Manipulation of the double key. (The key A is lowered. In this position, the exploring electrode is connected to the negative pole.)

If the key B is now lowered, a make is again produced, but since the negative pole of the cell has thus been connected with the passive electrode, the active electrode will be *positive*.

By simply manipulating the keys, this instrument can therefore be used to transpose the polarity of the electrodes, and to effect make and break. Its convenience renders it almost indispensable in galvanic exploration.

In the portable galvanic battery which one of us has had constructed (fig. 2), the double key mechanism is fitted alongside the apparatus for graduation and measurement.

The organism reacts to the continuous electric current as an electrolyte, and consequently follows the laws of electrolytic polarisation. In other words, the passage of the electric current develops an electromotive force of polarisation within the organism, antagonistic to that of the inducing current. The intensity of this current may reach such a degree in certain conditions that the results of electrical exploration may be affected by it. It will readily be observed from the diagram of Courtade's key that at the moment of break (release of the key) (fig. 5), the polarisation current, induced throughout the make, is short-circuited across the key. This is an advantage from the point of view of the next make of the exploring current, but at the moment of break, the make of the polarisation current superimposes its effects on those of the break of the exploring current. Since the galvanometer registers the sum of the intensities of the two superimposed currents, it follows that, in determining the "break" threshold, the intensity recorded will not be the actual intensity required for the threshold stimulus.

The double key is therefore a defective method for studying breaks; preferable to it is a simple key which does not make the polarisation current at the break of the exploring current (Bourguignon).[1] On the other hand, the passage of the polarisation current through the double key in the interval between two makes of the exploring current obviates interference with the latter by any secondarily induced current. As it is usually considered sufficient in electro-diagnosis to investigate make contractions, it will be seen that with the double key these can always be obtained pure.

In permanent installations the necessary instruments for electro-diagnosis are usually mounted on a

[1] If one of the keys is kept permanently down, the Courtade key becomes a simple key.

wall-bracket or a table. These *electro-diagnosis tables* are arranged in such a way that both faradic and galvanic current are connected with a single apparatus for utilising them, which renders unnecessary the disconnection of the wires. This commutation of the current is effected by a two-way switch, known as *Watteville's commutator.*

Lastly, an *interrupting metronome* effects rhythmic interruptions and reversals of the current, acting, if desired, in place of manual manipulation of the Courtade key. Some more complicated electro-diagnosis tables are also fitted with various instruments, voltmeters, condensers, etc.

Electrodes.—In exploring motor nerves and muscles

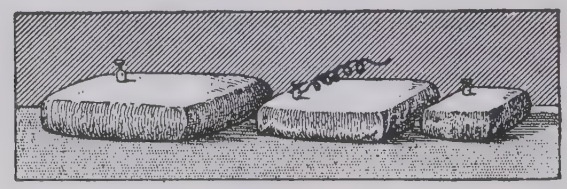


FIG. 7.—Flat electrodes.

the current is applied by means of *sponge-electrodes.* Of these there are two forms, the *flat* and the *button-shaped.* The former (fig. 7) consist of a malleable metallic plate, unfortunately still sometimes supplied by the manufacturers covered with chamois leather, but which it is more satisfactory to cover with a layer of absorbent cotton material. Flat electrodes act as what are known in electro-diagnostic technique as the *indifferent* electrodes, since their only purpose is to make the circuit through the patient; and they

can consequently be placed anywhere on the surface of the body. It is usual to apply them to the middle of the chest or back, where they are secured by means of an elastic band, after being moistened with warm water.

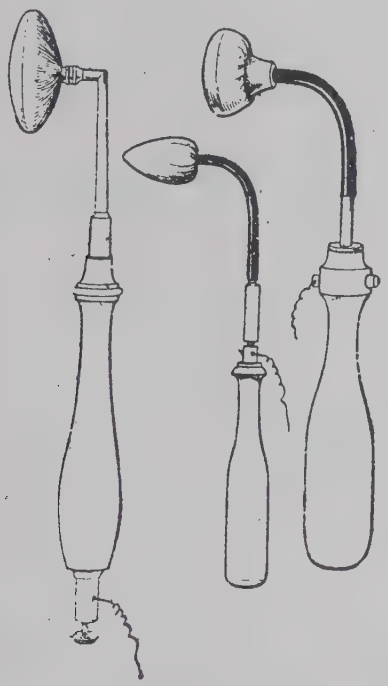


FIG. 8.—Exploring electrodes.

Button-shaped electrodes, known also as tampons, (fig. 8), consist of a carbon extremity covered with chamois leather or absorbent material, attached to the end of a straight or curved handle.

Used to localise the stimuli to the nerve or muscle, they constitute, in electro-diagnosis, the *active electrode*, the testing, or differentiating electrode.

The dimensions of the exploring electrode should always depend on those of the organ concerned. In the case of large muscles, electrodes of large diameter (2 to 3 cm.) are used; for small muscles, electrodes of smaller surface (5 to 8 mm. in diameter), or olive-shaped electrodes.

The exploring electrode introduces into the organism a current of the same intensity as does the indifferent electrode, but through a much smaller surface of entry. The relation between the intensity and the surface area is known as the *density* of the current. The density therefore increases with a decrease in size of the electrode.

In certain cases, particularly with the faradic current, it is necessary to localise the current to a single nerve or muscle. To apply this "bipolar" method it is best to use two small olive-shaped tampons held in one hand.

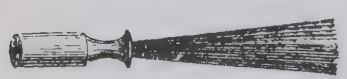


FIG. 9.—Duchenne's brush.

An investigation of cutaneous sensations with the faradic current is sometimes carried out with sponge electrodes, but it is more usual to employ metal electrodes, such as *Duchenne's brush* (fig. 9), a small brush formed by a bunch of brass wires.

Duchenne's brush can only be used for unipolar exploration. Now in cases of complete anæsthesia or marked hypoæsthesia, the strong currents which will have to be employed will affect both nerves and muscles simultaneously, the more so as the explora-

tion is continued nearer to motor points. Contractions produced in this way will interfere considerably with the investigation of sensation. It is therefore well to adopt the bipolar method, which can be done by employing some bipolar metallic electrode, connected by two wires with the coil. *Tripier's rake* (fig. 10) is constructed on this principle: a racquet-shaped instrument from which project two sets of blunt

FIG. 10.—Tripier's rake.

brass points, respectively connected with the two poles of the coil.

Condensers.—The use of the condenser in electro-diagnosis has been vigorously championed in Austria by Zanietowski, and in France by Doumer and Cluzet. Considered too complex, however, owing to the calculations which it involves, it has been almost systematically discarded by the majority of electrotherapists. It is not, however, impossible that a reorganisation of the system of electro-diagnosis may reinstate it as a generally accepted method.

For reasons which will be explained later, certain authors have proposed to employ the method of condensers, *charged to varying degrees*, in electro-diagnosis. In this method condensers of different capacity are charged to an increasing voltage, thereby determining for any given condenser the smallest voltage which will evoke the threshold of muscular contraction.

Instead, however, of determining the minimal stimulus by varying the potential of the discharge from a standard condenser, it may be determined by means of a constant potential and a series of condensers of increasing capacity. This is the principle of the "method of condensers of variable capacity," the use of which, though still limited, may be required more generally in the future.

The duration of the discharge from a condenser is in proportion to its capacity.[1] With a series of condensers of increasing capacities, and charged to the same potential, it will therefore be possible to apply discharges to the nerve or muscle differing in the matter of *duration*.

Cluzet's *condenser of variable capacity* (fig. 11) consists of a series of condenser plates of respective capacities 0·005, 0·01, 0·02, 0·02, 0·05, 0·1, 0·2, 0·2, 0·5, 1, 3, and 5 microfarads.

On the upper surface of the box in which they are enclosed is

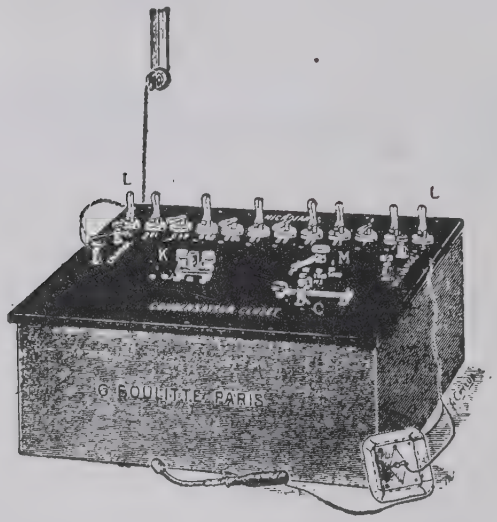


FIG. 11.—Condenser of variable capacity.

a system of spring keys by means of which a single condenser, or a combination of any number, may be used. Capacities graduated from 0·005 to 10 microfarads are therefore available.

A plug connection supplies the apparatus from a source of continuous current (preferably a 110 volt circuit). A two-way Morse key effects successive charge and discharge into the utilisation circuit. Finally, a series of resistances (1,000, 2,000, 5,000 ohms) may also be introduced into this circuit. The current is conveyed

[1] To be more exact, the duration of the discharge from a condenser depends upon the capacity C and the resistance R. The product $RC = t$ is the time constant of the condenser. If R is constant, the duration of the discharge varies solely with the capacity of the condenser.

to the patient by means of ordinary electrodes (active and indifferent); the polarity is reversible at will by a commutator. No measuring instrument is fitted; this, however, would serve no purpose, since the determination of the capacity which gives the threshold (liminal capacity), decides the principal question of the investigation, the duration of stimulus. For normal muscles and nerves this liminal capacity is almost exactly 0·02 microfarad. But in a pathological condition this is inadequate. By manipulating the keys higher capacities are gradually introduced until the minimal contraction is obtained.

Sometimes, particularly when the muscle reacts to the galvanic current with a very slow contraction, a capacity of 10 microfarads produces no contraction. One of the resistances must then be introduced into the discharge circuit.

III. The Normal Reaction of Motor Nerves and Muscles

The Meaning of Threshold.—All modes of electrical stimulation, such as the faradic current, static discharges, discharges from condensers, and varying states of make and break of the galvanic current, if applied to a healthy muscle or its motor nerve, will produce muscular contraction; that is to say, the passage of the muscle from the state of repose into that of activity.

For the effects of stimulation to be produced, the stimulating agent must reach a certain definite measure, below which it remains ineffective. This lower limit is the threshold stimulus, and the contraction which it evokes, in response, is the minimal contraction.

All stronger stimuli cause contraction, and the energy of the latter increases with the intensity of the exciting current. This proceeds until a limit is

reached, known as the maximal contraction, the energy of which cannot be increased by an increase of current-intensity. The point at which this maximum is reached is difficult to determine, but the value of the exciting current, at the moment of transition from an inadequate to an effective stimulus, is capable of much easier and more exact measurement. For this reason the threshold has been adopted in practice as a measure of excitability.

Excitability and Conductivity. — A motor nerve causes a muscle to contract only when the stimulus is conducted to the extremity of that nerve. This property of the nerve by which the stimulus is conducted along it, conductivity, is absolutely distinct from excitability. Several experiments in elementary physiology demonstrate the fact that these two properties of the nerve are independent. Of these the most classical is Grunhagen's experiment.

A nerve-muscle preparation is obtained, and the nerve is passed into a tube where a current of carbonic acid is circulating. It can then be shown that if the nerve be stimulated in its course through the tube, there is no muscular response. On the other hand, stimulation further up the nerve produces muscular contraction; conductivity is therefore preserved. The opposite phenomenon, however, is produced when the nerve is submitted to the action, not of acid, but of alcohol or ether vapour. In this case the conductivity is the first to disappear.

The independence of excitability and conductivity is similarly observed in electro-diagnosis.

Thus, Erb was the first to observe that in the common radial paralysis caused by momentary compression, stimulation of the nerve above the point of com-

pression (in the axilla or at Erb's point) is incapable of producing contraction of the extensors of the forearm, whereas it is effective when the electrode is applied below the point of compression. In this case the radial nerve, although its excitability is preserved, has lost its power of conducting voluntary impulses and of transmitting an electrical stimulus. Conversely, when a nerve which has lost its motor functions and electric excitability begins to recover these properties, the earliest phenomenon is usually recovery of the power of voluntary movement, after which the nerve above the lesion becomes excitable, and later still, excitability below the lesion is recovered. Here again there is therefore dissociation of excitability and conductivity.

These two different properties of the nerve, excitability and conductivity, are usually attributed to two different elements in the neurone. The function of conductivity, both voluntary and electrical, is concerned with the axis cylinder, while the function of excitability is connected with the myelin sheath, and it is by the myelin that electric stimuli are transmitted.

Now, in nerve lesions it appears that changes in the myelin precede those in the axis-cylinder.

At the same time the axis-cylinder should apparently recover its anatomical integrity earlier than the myelin, since in the process of regeneration a nerve recovers its power of conducting voluntary impulses earlier than its excitability.

IV. Stimulation with the Faradic Current

Single Faradic Contractions from Induction Shocks (fig. 12).—When a motor nerve or muscle is stimulated by means of an induced current progressively increasing in intensity, produced at break of the interrupter, it is found that with a low intensity only the wave induced at break produces an effect. To obtain a contraction with the wave induced at make, the intensity must be increased considerably, and

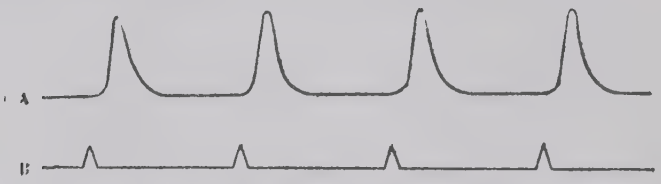


Fig. 12.—Single faradic contractions (A). At B the induction shocks (waves at break).

with such a current the break contraction is decidedly more forcible than the make.

The greater intensity and shorter duration of the break wave are the two physical factors which explain this difference between the make and break waves.

The total duration of the muscular contraction being about one-tenth of a second, a succession of single contractions will be obtained by adjusting the interrupter for a lower frequency than 10 stimuli per second. In practice, however, to obtain clearly distinct contractions, there must be an interval of rest between each at least equal to the time of the contraction. The contractions are only clearly isolated with a frequency of 1 to 2 stimuli per second.

Physiological Tetanus.—When, on the other hand, a stimulus reaches the nerve or muscle during the period of relaxation after a previous contraction, a second contraction prolongs the first and increases its amplitude. A succession of stimuli applied under

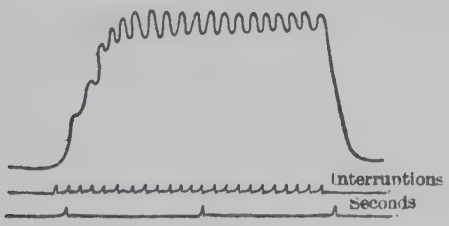


FIG. 13.—Incomplete faradic tetanus.

these conditions produces *incomplete physiological tetanus* (fig. 13). This phenomenon is given by frequencies of from 3 to 15 interruptions per second.

By adjusting for higher frequencies, a point is reached at which the stimuli recur with sufficient

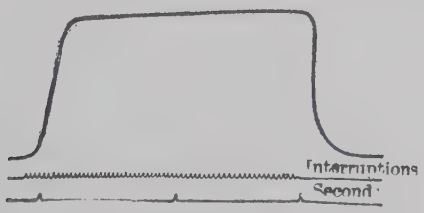


FIG. 14.—Complete faradic tetanus.

rapidity to coincide with the end of the contraction period caused by the preceding stimulus. Hence the muscle has no longer any time to relax; in spite of the succession of stimuli, it displays the picture of a single contraction. This is spoken of as fusion of contractions, or *complete physiological tetanus* (fig. 14).

A further increase of frequency beyond that producing complete tetanus only increases the amplitude of the contraction.

The minimum frequency to produce tetanus varies with the subject and with the muscle. As a rule, it is given by a frequency of 18 to 25.

Current of Quantity and Current of Tension.—It is usual to say that the secondary current produced in the coil with fine wire (current of tension) acts on the sensory apparatus, whereas current from a coil with coarse wire (current of quantity) acts on the motor apparatus. These expressions suggest a specificity which does not exist. It is certain that coils with fine wire, particularly when the current is applied by means of dry electrodes, have a marked effect on sensory nerve-endings, and the more the tension is raised the more painful does the current become. With moist electrodes the sensory effect is less, but it is always more marked than with the current of quantity. With the coil of coarse wire and with moist electrodes, pronounced motor effect can be developed by approximating the coils, without causing painful sensation. If, however, a contractile response is not obtained at the maximum approximation, the intensity must be insufficient. A contraction can then be obtained with the finely wound coil, which owing to the greater tension of the current will give a greater intensity. In certain cases this contraction may, instead, be obtained by using a coil giving a current of lower tension (medium winding), which conse-

quently will produce only a moderate degree of painful sensation.

V. Stimulation with the Galvanic Current

The Law of Contraction.—The stimulation of a nerve or muscle by a continuous current in the permanent state is ineffective with low intensities of current. With adequate intensities there results, not a muscular contraction, but an increase of the normal tone (Remak's galvanotonic contraction). To cause contractions with the galvanic current it is necessary to produce sharp variations of intensity (Du Bois-Reymond).

In experimental physiology, when two electrodes are applied to an exposed motor nerve, and a current of moderate intensity is sharply made and broken, a twitch is observed in the muscles innervated by the nerve excited, at the instant of sudden make and sudden break.

If the intensity of a constant current already traversing the nerve is suddenly diminished or increased, the same phenomenon is observed.

The contraction at make and that at break, however, only occur with currents of moderate intensity. With weak currents, sufficient to produce only one contraction, the twitch only occurs at the make; again, with strong currents only one twitch is observed, which takes place at the make if the current is descending, and at the break if it is ascending.

These peculiarities constitute what is known as

Pflüger's law of contraction. But although this law is regarded as one of the fundamental discoveries of electrophysiology, it is now only of secondary interest from the clinical point of view, by reason, in particular, of the fact that it is almost impossible, unless very strong currents are used (Brenner), to reproduce the conditions of Pflüger's experiment through the skin in man.

The Unipolar Method of Stimulation. — Pflüger's law regards the direction of the current, whether ascending or descending, as the essential factor in determining the order of the muscular responses.

It was subsequently questioned, however, whether these phenomena really depended on the direction of the current, or whether they did not follow simply from the specific action of each pole. To decide this question, a means must be found of studying their respective actions separately.

The unipolar method of stimulation, introduced in physiology by Chauveau, and shortly afterwards by Brenner as a clinical method, apparently proved the specificity of each of the poles.

In this method, the nerve is investigated by stimulation with *a single electrode*; the other, known as the *indifferent or passive electrode*, being fixed at a point some distance from the nerve concerned.

The Order of Appearance of Contractions: The Normal Formula.—In man, the effects of unipolar stimulation may be studied by applying a large indifferent electrode to some point, preferably the patient's back,

and applying a tampon electrode, 2 sq. cm. in area, over an easily accessible nerve. Under these conditions, if the intensity of the current be gradually increased, the following phenomena are observed.

At first no contraction is produced until the thres hold intensity is reached; this varies with different nerves from 0·1 to 5 milliamperes.[1] Then, with a weak current, and the active electrode connected to the negative pole, the varying state of make produces a *short, sharp, and rapid* contraction, while the break has no effect. The same stimulus with the same strength of current, but with the positive pole in connection with the nerve, produces no contraction, either at make or at break.

With a stronger current, and the active electrode connected to the negative pole, the make gives a

[1] The degree of intensity required to excite different nerves varies with the nerve concerned, the regulating mechanism, the surface area of the active electrode, etc. Thus with electrodes 3 sq. cm. or more in area, a rather stronger current is required to obtain the threshold than with smaller instruments. Adjusting the intensity with a rheostat, or a resistance introduced into the stimulating circuit, gives higher values for the threshold than are obtained with a potential reducer or a cell-collector. Lastly, there may be very wide individual variations. Usually, with a 1 to 2 sq. cm. electrode, and a collector, the threshold is as follows:

Musculo-cutaneous	0·1	ma. to	0·3	ma.
Ulnar (in the sulcus)	0·5	,, ,,	2·5	,,
,, (in the arm)	0·2	,, ,,	1·0	,,
Median	0·3	,, ,,	1·5	,,
Radial	1·0	,, ,,	3·0	,,
Facial	0·5	,, ,,	2·0	,,
Crural	0·5	,, ,,	2·0	,,
External popliteal	0·2	,, ,,	2·0	,,

more forcible contraction than before: no twitch occurs at the break. If the active electrode is made positive, a current of the same intensity produces: (1) a fairly strong contraction at make, (2) a weaker contraction at break.

With a still stronger current, and the active electrode negative, we obtain, (1) a persistent tetanic [1] contraction at make, (2) a slight twitch at the break. The latter is only perceptible with a very strong current, which is often painful.

If the active pole is positive, contractions in the same ratio as in the preceding case occur at make and break, both, however, with considerable force.

In observing the intensities at which these different contractions appear, they are seen to succeed one another in the following order: first KCC, then ACC, then AOC, and lastly KOC; this is usually represented by the conventional formula:

$$KCC > ACC > AOC > KOC;$$

it is sometimes written KCC*te* > ACC > AOC > KOC, to indicate the tonic nature of the kathodal closing contraction when strong currents are employed.

In reality, as Cardot and Laugier point out, this formula indicates, not the order of appearance of

[1] We use the word tetanic here out of respect for the old terminology. But as Bourguignon very rightly said, the word tetanus has a definite meaning in physiology, suggesting the idea of a fusion of simple contractions. Now the galvanic current produces a simple, sustained, and tonic contraction; that is, a galvanotonic contraction.

these stimuli, but the magnitude of the contractions with a current of sufficient intensity to produce all four of them. The exact formula of their order of appearance would be :

$$\text{Threshold KCC} < \text{threshold ACC} < \text{threshold AOC} < \text{threshold KOC.}$$

This formula is the general rule. With certain nerves, however, the positive break contraction sometimes appears with an intensity equal to, or less than, that necessary for obtaining the positive make contraction. This peculiarity, already described by Remak and Erb, is not infrequently observed in the radial, the external popliteal, and sometimes the median and ulnar nerves. The formula then becomes :

$$\text{KCC} > \text{AOC} \geq \text{ACC} > \text{KOC.}$$

When, instead of applying the active electrode to the nerve it is applied *over the muscle*, we observe that the order of appearance of the contractions is the same. The formula is identical, with the following modifications :

1. A current of liminal intensity for the muscle causes a relatively powerful contraction if applied to the nerve ; the latter is therefore more excitable than the muscle.

2. Break contractions require a greater intensity on the muscle than on the nerve : such an intensity as may become painful. The KO contraction should

not, at times, be produced, since the current necessary to produce it would be unbearable.[1]

3. The galvanotonic contraction KCC*te* is much more difficult to obtain than on the nerve.

This order of appearance of contractions is common to man and animals. In animals, however, the results are no longer the same when, instead of determining the smallest intensity of current necessary to provoke contraction, currents of increased intensity are applied. Instead of the predominance of KCC over ACC, it is often observed that KCC and ACC are equal, or even ACC may be greater than KCC.

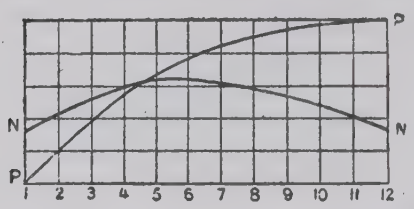


FIG. 15.—Variation in amplitude of contraction produced by each pole as determined by the intensity of the current (Chauveau).

Chauveau has shown, in fact, on the frog, that with regularly increasing unipolar excitations, the negative response increases in amplitude and duration, at first quickly, then more slowly, whereas the positive increases in a regular and constant manner up to the maximal contraction. It follows that for a certain intensity, the contractions are equal; the ACC becomes equal in force and amplitude to the KCC (Chauveau's neutral point) (fig. 15). With

[1] The AOC is obtained with relative ease on such large muscles as the biceps, supinator longus, flexor digitorum, vastus internus, sterno-mastoid, and trapezius. But with small muscles such as those of the face, more than 5 ma. are sometimes required in the normal state, and produce very painful sensations. The KO contraction is naturally still more difficult to obtain.

still greater intensities, the ACC predominates entirely, contractions with the negative pole remaining stationary or even beginning to weaken. Thus an actual inversion occurs. According to Boudet of Paris, if the strength of the current be increased still further, contractions with the positive pole diminish in their turn, then again equalise those from the negative pole, and finally diminish more rapidly than the latter. There would therefore be a second neutral point.

With break currents the opposite phenomenon occurs.

In the normal state in man, it is difficult to demonstrate this phenomenon, as a current of sufficient strength cannot be used. But in a pathological state, this is not so, as will be seen later (Bourguignon).

The Supposed Specific Action of the Poles.—Results of the unipolar method of investigation possess the value belonging to observed facts. Each of the poles, at make and at break, has a different exciting power.

It is for this reason that in electro-diagnosis a very large indifferent electrode is used on the one hand, and on the other, an active electrode transmitting the current at a very high density, a procedure by which the effect of one of the poles is absolutely excluded, through an increase in the exciting power of the one of which the action is being studied.

This supposed polar specificity is, however, only apparent. It is explained in the law of electro-

physiology stated simultaneously by Pflüger, von Bezold, and Brenner (1859) : *stimulation originates at the kathode at make, at the anode at break.* Brenner, then de Watteville, Erb, and finally Bourguignon, proceeded to demonstrate that this law, based on experiments with an animal, by the bipolar method, was true for man, and with the unipolar method.

At the make, when the testing electrode is negative, the stimulus originates from it ; when it is positive, the stimulus passes from the indifferent electrode, and impinges on the nerve or muscle over a much wider area (virtual electrode), and consequently at a much lower density. This reduced density can only produce a contraction of a lesser intensity. At the break, the negative pole being on the nerve or muscle, the stimulus passes from the indifferent electrode, and reaches the nerve or muscle at a lower density than would be the case were the positive electrode applied to the organ concerned. Hence it follows that the AOC should be greater than the KO contraction.

In reality, when we stimulate a nerve or muscle alternately with negative and positive, we are not bringing a selective action of each pole into play, after excluding effects from the pole of opposite name. We simply effect stimulation of the organ at a density which varies according to the point of origin of the stimulus.

VI. Exploration

General Technique.—To carry out an electro-diagnostic examination under good conditions, the region to be explored should be placed in a good light, and in such a position that the muscles to be stimulated are in a state of complete relaxation. For this reason, it is often more convenient to examine the patient lying on a bed or a couch.[1]

It is always well, and all classical works are agreed on this point, to commence with faradic exploration, first the nerve and then the muscle. Beginners will do well to follow this rule, but experienced electrologists prefer to begin with the galvanic exploration of muscles. This, owing to the form of the contraction and the strength of the current required, enables conclusions to be formed rapidly. It shows immediately, at the first touch of the key, whether the reaction of degeneration is present or not, and subsequent faradic exploration completes this original observation by indicating whether the reaction of degeneration is complete or partial.

Finally, the passage of the continuous current sometimes reveals latent faradic excitability in the muscle (*v.* p. 81). By beginning with galvanic exploration, it will be possible to decide more definitely whether faradic excitability is absent or preserved, which is

[1] It is often important, for reasons which will be explained on p. 80, to preface an examination by immersing the limb concerned for some time in warm water.

of the greatest importance from the point of view of the degree of the reaction of degeneration.

The examination of muscles with the galvanic current should concern itself with the nature of the contraction, the minimum strength required to obtain the threshold, and the order of appearance of the contractions. As a rule the break contractions are not studied; the characteristics of the make contractions alone usually suffice to indicate the degree of hypo- or hyper-excitability, the form of the contraction, and the existence or absence of the inversion reaction.

When the galvanic examination of the muscles has been completed, the faradic examination is undertaken; finally, the nerves are examined.

Either a frequently interrupted faradic current, or single shocks, will be used, according to circumstances (*v.* p. 53). Whenever unilateral lesions are concerned, the nerves and muscles of the unaffected side should be examined from time to time, as their normal reactions are of the utmost value for comparison.

Unipolar Method.—The electrodes by which the current is to be transmitted to the patient are located according to the principle of the unipolar method: one, the indifferent electrode, at some point on the dorsal or lumbar region, or in front of the sternum (in such a way that the sagittal plane of the body cuts it into two equal parts); the other, the testing electrode, upon the nerve or muscle to be examined. The latter will be chosen with suitable diameter:

small (8 to 10 mm. in diameter) for the examination of the nerves and muscles of the face, the small muscles of the hand; medium (2 to 2·5 cm. in diameter) for the examination of muscles of moderate size; and larger for thick muscles, such as those of the calf, or the quadriceps femoris.

Bipolar Method.—It often happens that when the

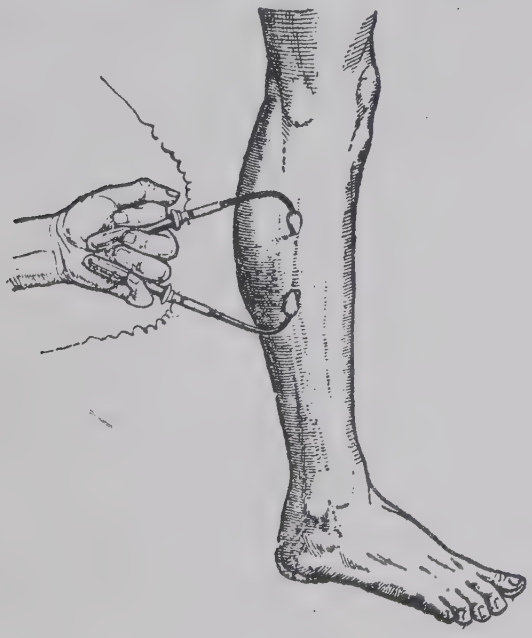


FIG. 16.—Bipolar method.

faradic excitability of a muscle is much diminished, the strong faradic stimulus employed to produce contraction is conducted to the healthy muscles of the region. In this case the limb under examination is violently shaken, and the contraction of neighbouring muscles obscures that of the muscle under

observation, the excitability of which cannot, therefore, be estimated.

The indication then is to localise the action of the current to this muscle. For this purpose the wires from the coil are connected with two small electrodes of suitable dimensions, preferably small olive-shaped electrodes, which are applied approximately over the region of the ellipse formed by the fleshy belly of the muscle. This is the bipolar method, which Duchenne (of Boulogne) found so satisfactory (fig. 16).

With the galvanic current, the examination should always, as a matter of principle, be carried out by the unipolar method. When, however, the excitability of the region under examination is much reduced, stimulation, owing to the great strength of current required, again provokes violent contractions in neighbouring regions which are unaffected by the lesion. It is therefore sometimes of advantage to bring the indifferent electrode close to the region under examination, to fix it at the root of the limb, or again at a short distance above the muscular area concerned.

To avoid the masking of the reactions of the muscles affected with the reaction of degeneration by those of healthy muscles, produced by a strong current, Larat advises gentle rubbing of the muscle under examination with the testing electrode, and gradually increasing the strength of the current until a response is obtained. At the moment when the electrode comes in contact with the skin, the healthy

muscles undergo a sharp, rapid, and only momentary contraction, followed by the slow contraction of the degenerated muscle.

More scientific, but yet outside the domain of practice, is the arrangement, devised by Lapicque, of a condenser placed *in parallel* with the stimulating circuit, the latter being rendered more resistant by an additional resistance, intended to retard the making of the current. The galvanic wave is thus rendered too slow to excite healthy *striped* muscle, and only provokes the slow contraction of the degenerated muscles.

Motor Points.—Trans-cutaneous stimulation is only practicable when the nerve or muscle is superficially situated, *i.e.* only a short distance beneath the skin. Deep nerves and muscles cannot be investigated.

Nerves are not usually accessible except in their exposed parts, at points where they are not surrounded by muscle. (Example: The median nerve between the flexor tendons above the wrist, the ulnar in the epitrochlear-olecranon sulcus.)

Sometimes, however, it is difficult to reach them, as in a case where the nerve runs alongside the body of a muscle. Here stimulation causes a simultaneous contraction of this neighbouring muscle, which, in expanding, often intervenes between the electrode and the nerve. (Example: The radial nerve in the lower part of the musculo-spiral groove.)

All the fleshy part of a *muscle* is excitable, but this excitability is always more pronounced over a limited

area, which generally corresponds both to the most superficial part of the muscle, and to the point of entry of the nerve which supplies it. These areas where nerves are accessible, or where muscles can most readily be excited, are called *points of election*, or *motor points*.

Muscles usually possess *one* motor point, but a few multi-fascicular muscles have *two*, or even three, like the deltoid.

It is with these points that the exploring electrode is concerned.

All works on electrotherapy contain plates showing the topography of the motor points; that is, their position on the surface of the skin. The electrologist, however, should know the situation of these points sufficiently well by heart to dispense with frequent reference to diagrams, which complicates an examination considerably.

To acquire a rapid familiarity with their situation it is much more profitable, in our opinion, to use good anatomical plates than to study the diagrams referred to above.

A mental dissection of the region to be examined suggests the relations of the parts, and assists the memory of these points of election, giving the hand which is manipulating the electrode that assurance and precision required for their "discovery."

Lastly, it must be remembered that the classical points are subject to individual variations in position, so much so that the motor point is often discovered only after a succession of tentative stimuli over a given area.

The classical plates all show an inordinately large number of motor points. In addition to those which it is absolutely necessary to know, there is a whole

series of points which are never examined, or only in such exceptional conditions [1] that it seems to us altogether useless to reproduce them here, particularly as the situation of the principal ones will be all the more evident in consequence. Finally, we have definitely broken with old tradition in diagrams of motor points by showing, as in works on operative medicine, such anatomical relations as will enable the operator to locate these points with ease and rapidity.

THE PRINCIPAL MOTOR POINTS [2]

THE MOTOR POINTS OF THE FACE

Examination of the muscles of the face should be carried out with a small electrode, less than 1 cm. in diameter. The faradic current is only employed in the form of single shocks, as far as possible of low tension, in order to reduce stimulation of sensory nerve-endings to a minimum.

1. **Facial Nerve.**—The facial nerve is stimulated either below the ear, between the mastoid and the ascending ramus of the mandible, the electrode being applied as if with the object of reaching the stylo-mastoid foramen, or in front of the ear, at the base of the tragus. It may also be reached by inserting a small conical electrode into the external auditory meatus, and moving this electrode downwards and forwards (Bergonié). Stimulation of the facial nerve causes contraction of all the muscles of the face.

The three branches of the facial nerve may be stimulated separately.

(1) Upper branch : on the temple, slightly outside and above the outer angle of the eye.

(2) Middle branch : over the most prominent point of the zygomatic arch.

(3) Lower branch : immediately above the angle of the lower jaw and slightly in front of it.

[1] As, for instance, the procerus (*pyramidalis nasi*) and nasalis in the face, the supinator brevis and anconæus in the arm, the tensor fasciæ latæ and pectineus in the thigh, etc.

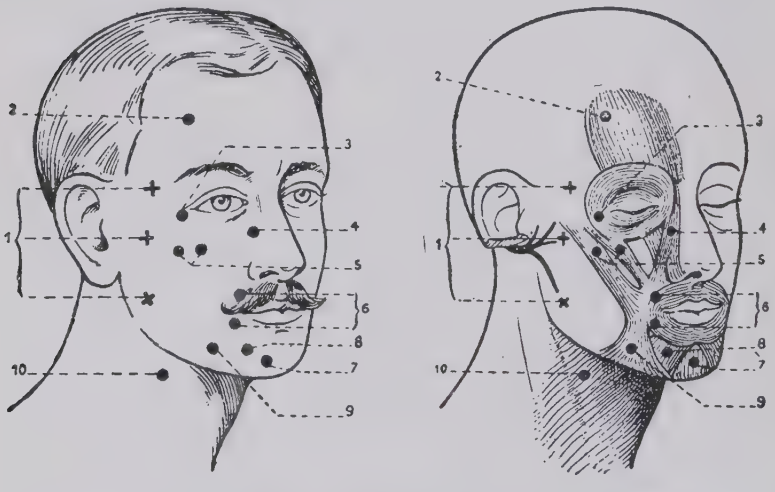
[2] The numbers correspond to those in the illustrations.

These three points are situated in an almost straight and vertical line passing through the most prominent point of the zygomatic process.

Care should be taken, in examining branches of the facial nerve, not to be led into error by contractions of the masseter and temporalis muscles (trigeminal), to which the stimulus is conducted when a current of sufficient strength is used.

2. FRONTALIS MUSCLE.—*Motor point :* over the prominence of the frontal bone,[1] above the external region of the orbit. Elevates the eyebrow and furrows the forehead.

3. ORBICULARIS OCULI.—*Motor point :* below the external angle of the eye. Closes the eyelids.



FIGS. 17 and 18.—Motor points of the face.

4. LEVATOR LABII SUPERIORIS ALÆQUE NASI.—*Motor point :* over the lower border of the nasal bone. The action is indicated by its name.

5. ZYGOMATICUS MAJOR AND MINOR.—*Motor point :* below the lower border of the malar bone, behind the insertion of the zygomatic process.

Draw the labial commissure upwards and outwards.

6. ORBICULARIS ORIS.—*Motor points :* two distinct points, for the upper and lower parts of the muscle, above and below the labial commissure. (During the examination of any muscles situated round the mouth, the latter should be slightly open.)

[1] Stimulation of the frontalis often causes phosphenes or giddiness.

Sphincter closing the lips.

7. LEVATOR MENTI.—*Motor point :* on the lower border of the mandible, just outside the middle line.

Draws the lower lip downwards and forwards, furrows and expands the chin.

8. DEPRESSOR LABII INFERIORIS.—*Motor point :* lateral to the foregoing, and slightly higher.

Draws the lower lip downwards and outwards.

9. DEPRESSOR ANGULI ORIS.—*Motor point :* immediately above the lower border of the mandible, at the junction of the posterior two thirds and anterior third of the horizontal ramus.

Draws the labial commissure downwards and outwards ; antagonises the zygomaticus major.

10. PLATYSMA.—*Motor point :* below and slightly anterior to the angle of the mandible. (It is important to differentiate between contractions of this muscle and those of the sterno-mastoid. For this reason the electrode is only applied very lightly to the skin, and not pressed deeply into it.)

Stretches the skin of the neck, and slightly depresses the labial commissure.

BUCCINATOR.—*Motor point :* within the mouth, in front of the anterior border of the masseter.

This muscle draws the cheeks inwards and the labial commissure outwards.

MOTOR POINTS OF THE SPINAL ACCESSORY NERVE AND CERVICAL PLEXUS

11. **Spinal Accessory Nerve** (EXTERNAL RAMUS).—*Motor point :* at the upper angle of the supra-clavicular triangle.

Causes contraction of the sterno-cleido-mastoid and trapezius (clavicular portion).

12. STERNO-CLEIDO-MASTOID.—*Motor point :* at the junction of the upper and middle third of the muscle.

Flexes the head, bends it to the side excited, and turns the face towards the opposite side.

13. TRAPEZIUS, CLAVICULAR PART (SPINAL ACCESSSORY NERVE.—*Motor point :* on the anterior border of the muscle, the edge of which is easily felt, and towards the middle of its clavicular portion.

Stimulation of the clavicular portion bends the head to the side stimulated, and slightly backwards, while the face is turned towards the opposite side.

14. MIDDLE PORTION (CERVICAL PLEXUS).—*Motor point :* in the vertebral groove towards the inner angle of the scapula. Raises the scapula.

15. Lower portion (cervical plexus).—*Motor point :* below the foregoing, at the level of the hollow of the axilla.

Draws the scapula towards the spine and carries the shoulder backwards.

Rhomboids (cervical and brachial plexus).—*v.* Brachial plexus, p. 40.

MOTOR POINTS OF THE UPPER LIMB

(1) Upper Radicular Group, and collateral branches of the Brachial Plexus

16. **Erb's Point.**—Two or three cm. above the clavicle, slightly outside the lateral border of the sterno-mastoid, opposite the transverse process of the sixth cervical vertebra (Chassaignac's tubercle).

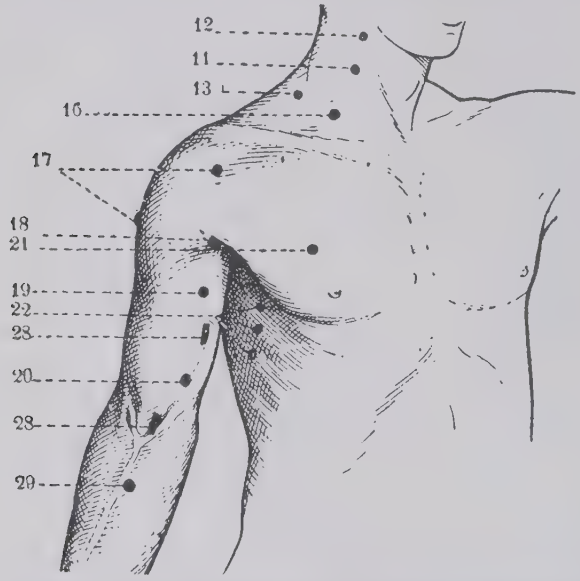


Fig. 19.—Motor points of the shoulder and arm (anterior aspect).

Stimulation of Erb's point causes simultaneous contraction of the four muscles of the Duchenne-Erb group; and of the pectoralis major (Secrétan, Mme. Klumpke). In total radicular paralyses of the superior type, stimulation at Erb's point gives rise to no contraction whatever. The build of the shoulder sometimes modifies the situation of this point appreciably.

17. Deltoid.—*Motor points :* on the anterior surface of the muscle approximately in the upper third; a second on the posterior

surface at the same level, and a third, stimulation of which causes contraction of the external fasciculi.

The anterior fasciculi raise the arm and carry it forward, the posterior carry it backwards.

18. **Musculo-cutaneous Nerve.**—*Motor point:* very difficult to find and to isolate; the electrode must be pressed very firmly

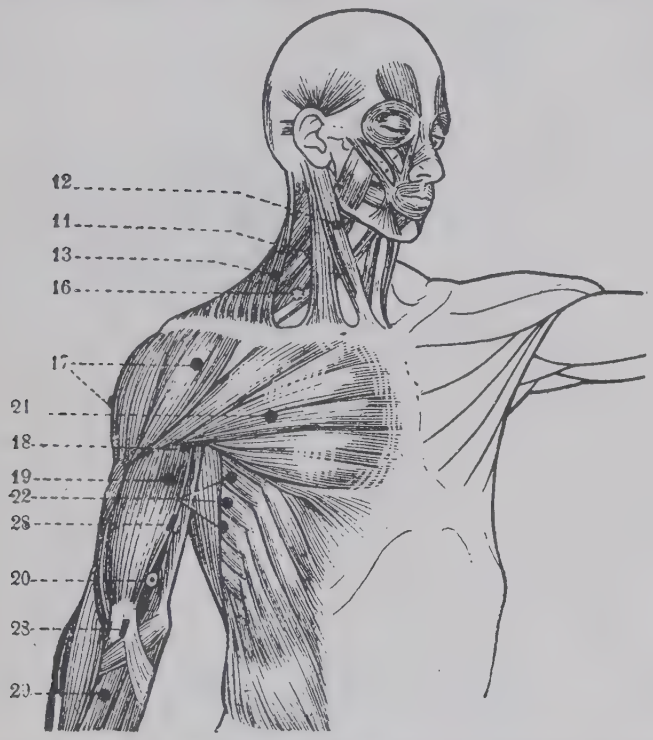


FIG. 20.—Motor points of the shoulder and arm (anterior aspect).

between the two heads of the biceps, or better between the coraco-brachialis and the biceps.

Causes contraction of the biceps and brachialis.

19. BICEPS.—*Motor point:* slightly below the antero-inferior border of the deltoid.

Flexes and supinates the forearm.

20. BRACHIALIS.—*Motor point:* to excite this muscle, a small electrode must be insinuated beneath the internal border of the biceps slightly below the middle of the arm, care being taken to avoid the median nerve. As a rule it is very difficult to isolate, since the

biceps or the median and ulnar nerves respond simultaneously to the stimulus and obscure the movement produced. It is sometimes easier to stimulate outside the biceps, between this muscle, the triceps and the upper border of the supinator longus. The flexors of the forearm must be kept in a state of complete relaxation.

Flexes the forearm on the arm.

SUPINATOR LONGUS (see motor points of the **Radial nerve**).

21. PECTORALIS MAJOR.—*Motor point :* above and lateral to the nipple on an imaginary line prolonging the anterior border of the hollow of the axilla.

Draws the arm downwards from a raised position, and rotates it internally.

22. SERRATUS MAGNUS.—*Motor points :* each digitation has a motor point. These are situated in the anterior part of the axilla along an oblique line with a posterior inclination from above downwards. Contraction of the entire muscle can be obtained by stimulating the nerve to the serratus magnus, which can be effected on the thoracic wall near the apex of the axilla, the arm being suitably raised in order to displace the pectoralis major.

Contraction of the serratus magnus draws the scapula forwards and outwards.

23. TERES MAJOR.—*Motor point :* this muscle connects the internal border of the scapula with the inner lip of the bicipital groove of the humerus. It forms part of the posterior wall of the axilla. Its motor point should therefore be looked for on the posterior wall of the axilla, near the apex of the latter. This muscle is difficult to isolate.

It adducts the humerus and raises the point of the shoulder.

24. SUPRASPINATUS.—*Motor point :* in the external angle of the supraspinous fossa.

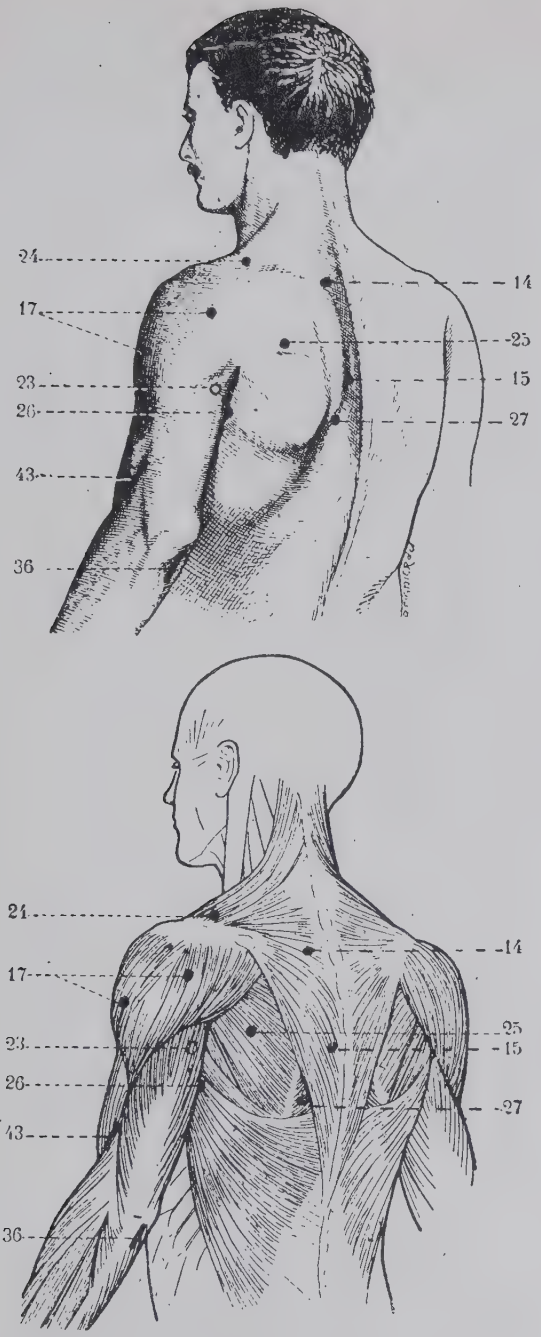
This muscle lies beneath the trapezius and can only be stimulated with great difficulty. It is only accessible when the trapezius is atrophied.

25. INFRASPINATUS AND TERES MINOR.—*Motor point :* the posterior border of the deltoid and the external border of the trapezius on separation bound a triangular aperture, the base of which is formed by the latissimus dorsi : it is through this aperture that the infraspinatus and teres minor are stimulated.

Rotate the arm externally.

26. LATISSIMUS DORSI.—*Motor point :* on the posterior wall of the axilla, between the scapula and the thoracic wall; it adducts, extends, and internally rotates the humerus, draws the scapula inwards towards the middle line, and the shoulder downwards.

27. RHOMBOIDS.—*Motor point :* these muscles can be stimulated in



FIGS. 21 and 22.—Motor points of the shoulder (posterior aspect).

the triangle bounded by the lower border of the trapezius, the vertebral border of the scapula, and the upper border of the latissimus dorsi.

Raises the internal angle of the scapula and draws it towards the spine, rotating it on the external angle of the bone.

(2) Median and Ulnar Nerves

28. **Median Nerve.**—*Motor points :* in the arm, along the internal border of the biceps, but as a rule simultaneous excitation of the ulnar and musculo-cutaneous cannot be avoided while stimulating at this point ; at the elbow, in the flexion fold medial to the biceps tendon ; at the wrist, at the level of the flexion folds between the tendons of the palmaris longus laterally and the palmaris brevis medially.

Stimulation at the elbow causes forcible pronation of the forearm, with flexion and closing of the hand (flexion of the fingers, opposition of the thumb) ; at the wrist, stimulation causes abduction of the hand and opposition of the thumb.

29. Palmaris longus.—*Motor point :* in the upper third of the muscle, on the ulnar border of its fleshy portion.

Flexes the hand.

30. Pronator teres.—*Motor point :* on its external border in the upper third.

Causes pronation of the hand.

31. Flexor digitorum sublimis.—*Motor points :* flexion of the last two fingers can be obtained by stimulation at a point towards the middle of the forearm, medial to the tendon of the palmaris longus. The point for the flexor of the index is in the lower third of the forearm, slightly within the middle line ; and just medial to this is the point for the middle finger.

Flexes the second phalanges of the four last fingers.

32. Flexor digitorum profundus.—*Motor point :* difficult to find ; separate stimulation almost impossible ; in the middle of the forearm, between the palmaris longus and flexor carpi ulnaris, towards the inner surface of the ulna.

Flexes the terminal phalanx of the last four fingers.

33. Abductor pollicis brevis.—In fig. 25 the electrode is shown on the motor point of this muscle. It will be observed that this point is proximal and lateral, on the outer border of the thenar eminence, close to the dorsal surface of the hand.

Carries the thumb forwards and inwards.

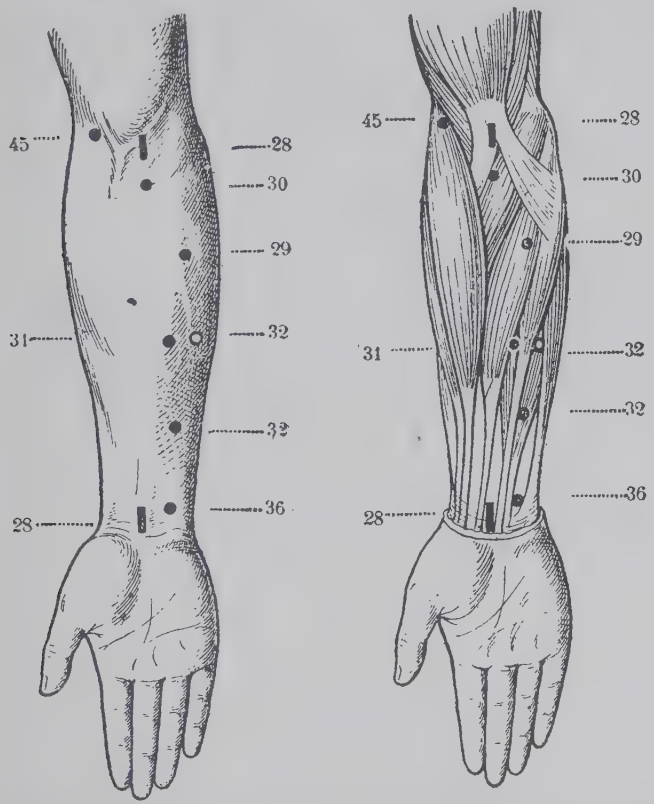
34. Flexor pollicis brevis.—*Motor point :* towards the internal border of the thenar eminence. It should not be forgotten that

this muscle consists of two parts, one supplied by the median, and the other by the ulnar nerve.

Draws the thumb inwards and forwards, and slightly rotates the first metacarpal in its long axis.

35. OPPONENS POLLICIS.—*Motor point:* slightly proximal and medial to the foregoing.

The three muscles of the thenar eminence should be stimulated



FIGS. 23 and 24.—Motor points of the forearm (anterior aspect).

with a very small electrode, such, for instance, as that used for the muscles of the face.

36. **Ulnar Nerve.**—In the arm: to avoid simultaneous stimulation of the median, the electrode should be applied about two fingers' breadths above the epicondyle.

At the elbow: the electrode is pressed into the epitrochlear-olecranal sulcus.

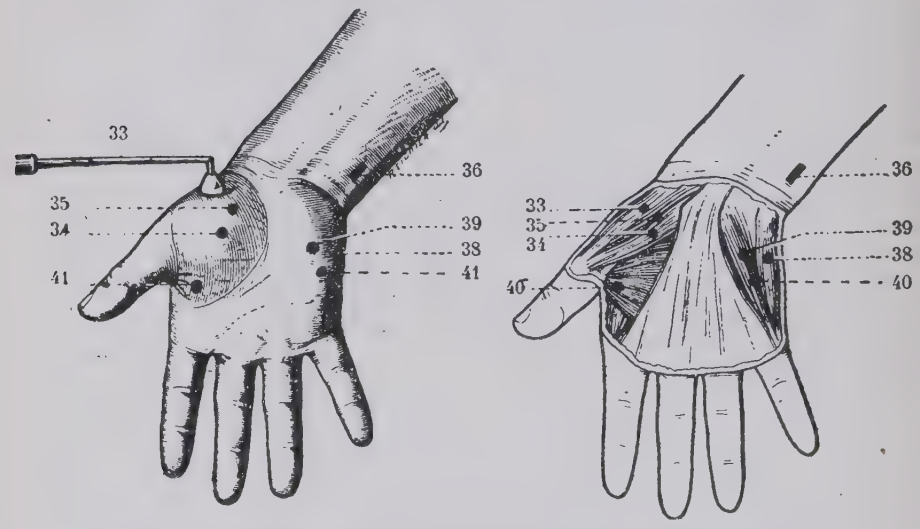
At the wrist: above the skin-folds and immediately lateral to the tendon of the flexor carpi ulnaris.

Stimulation at the elbow produces ulnar contraction of the fingers and flexion and adduction of the hand. Stimulation at the wrist draws the hand medially, and causes flexion of the three last fingers and adduction of the thumb.

37. FLEXOR CARPI ULNARIS.—*Motor point:* two fingers' breadths below the internal epicondyle.

Flexes and adducts the hand.

38. ABDUCTOR MINIMI DIGITI.—*Motor point:* on the ulnar border



FIGS. 25 and 26.—Motor points of the hand (palmar aspect).

of the hand, towards the middle of the hypothenar eminence (internal to the pisiform).

Abducts the last finger from the long axis of the hand.

39. FLEXOR BREVIS MINIMI DIGITI.—*Motor point:* in the centre of the hypothenar eminence (internal to the foregoing, and immediately distal to the hook of the unciform bone).

Flexes the last phalanx of the little finger and extends the two other phalanges.

40. OPPONENS MINIMI DIGITI.—*Motor point:* slightly below and external to the foregoing; difficult to isolate.

41. ADDUCTOR POLLICIS.—*Motor point:* on the internal side of the first metacarpal space (palmar aspect).

Abducts the first metacarpal and flexes the first phalanx.

42. DORSAL INTEROSSEI.—*Motor points :* at the distal ends of the inter-metacarpal spaces on the dorsum of the hand.

Flex the first phalanx and extend the two others. A more characteristic movement, however, is approximation of the two fingers adjacent to the interosseous space where the stimulus is applied.

(3) Radial Nerve

43. **Radial Nerve.**—The point for stimulation is often difficult to find. In order not to miss it a line should be imagined drawn from the middle of the posterior border of the deltoid V to the epicondyle. This line corresponds to the inter-muscular septum. In an adult a distance of approximately 10 cm. above the epicondyle is measured. This point is between the outer head of the triceps and the brachialis, above the first insertions of the supinator longus, at the point where the radial nerve perforates the septum.

It is well to use a fairly small electrode, which can be pressed deeply in between the brachialis and the most anterior fasciculi of the outer head of triceps. The radial may also be stimulated in the axilla, but it is difficult to avoid exciting other nerves in this region. In common radial paralyses, stimulation at this point may give rise to a false interpretation of the electrical reactions. Conductivity being interrupted below the point of pressure, faradic stimulation in the axilla only causes contractions in the triceps (the nerve to which rises above this point), and not in the extensors. When the electrode is applied on the humeral point, the latter muscles will be observed to respond to stimulation.

44. TRICEPS.—*Motor points :* for the long head, over this part of the muscle, in its upper third.

For the outer head : in the lower third of the external aspect of the arm.

For the inner head : in the centre of the internal aspect of the arm.

The triceps is the extensor of the forearm.

45. SUPINATOR LONGUS.—*Motor point :* on the anterior border of the muscle, in the skin-fold at the elbow.

Flexes the forearm in semi-pronation.

46. EXTENSOR CARPI ULNARIS.—*Motor point :* on the internal border of the ulna in its upper third, slightly below the olecranon.

This muscle extends the wrist and draws the hand inwards.

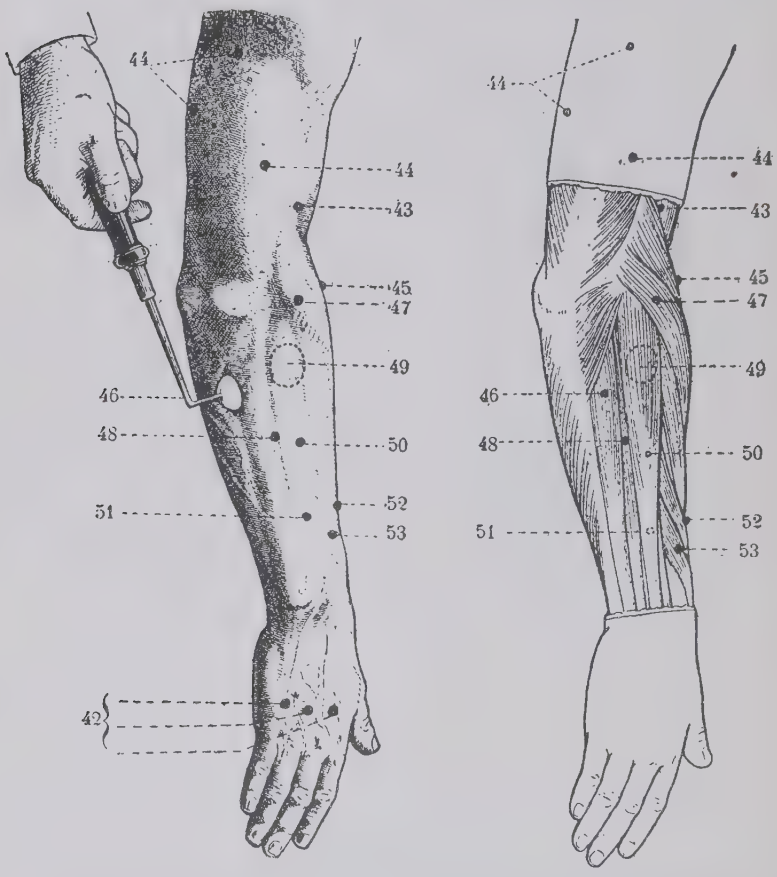
47. EXTENSOR CARPI RADIALIS LONGIOR.—*Motor point :* on the upper and outer part of the dorsal aspect of the forearm.

Extends the wrist and draws the hand outwards.

48. EXTENSOR MINIMI DIGITI.—*Motor point :* slightly distal and lateral to the point for the extensor carpi ulnaris.

49. Extensor digitorum communis.—*Motor point :* in the upper third of the dorsal aspect of the forearm.

An electrode of considerable size is required for stimulating all parts of the muscles simultaneously. Each can always be stimu-



Figs. 27 and 28.—Motor points of the forearm and hand (dorsal aspect).

lated separately if it is remembered that the points for the middle and index fingers are situated at the same level as the extensor of the little finger, and lateral to it, and those for the ring finger a finger's breadth above and slightly external to the latter.

This muscle extends the first phalanx on the metacarpal, and the hand on the forearm.

50. EXTENSOR INDICIS PROPRIUS.—*Motor point :* on the external border of the ulna, in its lower third.

51. EXTENSOR POLLICIS LONGUS.—*Motor point :* in the middle of the dorsal aspect of the forearm, four fingers' breadths above the line of articulation of the wrist. The electrode is pressed firmly on this point.

52. ABDUCTOR POLLICIS LONGUS.—*Motor point :* on the external border of the radius, where the muscle forms a prominence.

53. EXTENSOR POLLICIS BREVIS.—*Motor point :* slightly to the inner side of and below that for the abductor longus.

Extends the first phalanx of the thumb on the metacarpal and abducts the thumb.

MOTOR POINTS OF THE LOWER LIMB

(1) Anterior Crural Nerve

54. **Anterior Crural Nerve.**—The point for this nerve is below and slightly internal to the middle point of the inguinal ligament.

Stimulation causes forcible extension of the leg on the thigh.

55. SARTORIUS.—*Motor point :* in the upper third of the muscle or towards the middle.

Stimulation does not usually produce the physiological movement of flexion of the thigh on the pelvis, of the leg on the thigh, and lateral rotation of the thigh. It is sufficient to detect contraction of the muscle beneath the skin.

56. RECTUS FEMORIS.—*Motor point :* slightly above the middle of the anterior surface of the thigh.

Extends the knee, and draws the patella upwards.

57. VASTUS INTERNUS.—*Motor point :* to the inner side of the inner border of the rectus femoris, four fingers' breadths above the patella.

Draws the patella upwards and inwards.

58. VASTUS EXTERNUS.—*Motor point :* lateral to the external border of the rectus femoris, and slightly higher than that of the preceding muscle.

Draws the patella upwards and outwards.

(2) Obturator Nerve

59. **Obturator Nerve.**—This nerve can be stimulated at its exit from the obturator foramen by applying an electrode perpendicularly to the horizontal ramus of the pubis.

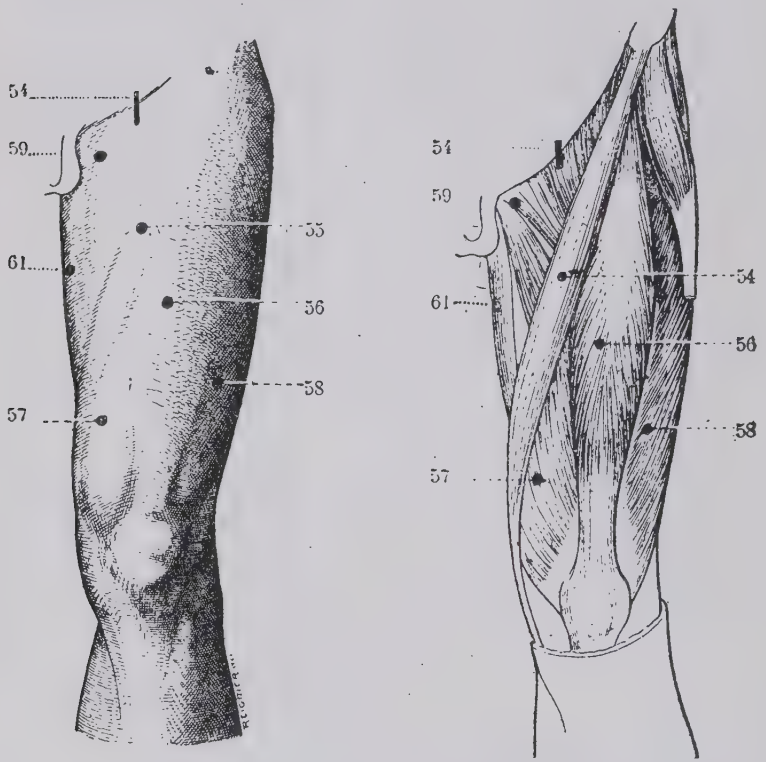
Stimulation causes adduction of the thigh.

60. Adductor magnus.—*Motor point :* in the upper third of the internal aspect of the thigh behind the median line.

Causes adduction and inward rotation of the thigh.

61. Gracilis.—*Motor point :* on the internal surface of the thigh on the median line towards its upper third.

Flexes the leg.



Figs . 29 and 30.—Motor points of the thigh (anterior aspect).

(3) Sciatic Nerve

62. **Sciatic Nerve.**—Point for stimulation: below the gluteal fold, slightly nearer to the tuber ischii than to the great trochanter. Stimulation is difficult in fat subjects.

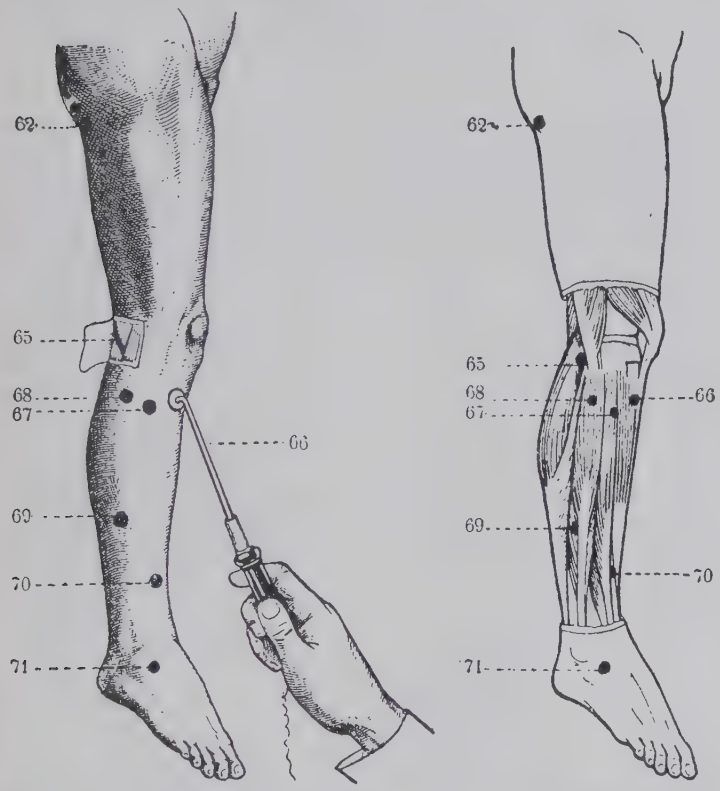
Causes flexion of the leg on the thigh and extension of the foot.

63. Biceps femoris.—*Motor point :* in the middle of the posterior aspect of the thigh, slightly lateral to the median line.

Only a twitch of the muscle can usually be produced.

64. SEMI-MEMBRANOSUS.—*Motor point:* towards the middle of the thigh, slightly to the inner side of the preceding.

Only a twitch is produced.



FIGS. 31 and 32.—Motor points of the leg (antero-lateral region).

(4) External Popliteal Nerve

65. **External Popliteal Nerve.**—This nerve can very readily be excited behind the head of the fibula as it winds round the neck of that bone.

Stimulation causes flexion of the foot on the leg.

66. TIBIALIS ANTICUS.—*Motor point:* immediately lateral to the crest of the tibia, 2, 3, or 4 cm. below the proximal extremity of that bone. In fig. 31 the electrode is on this point.

Flexes the foot and elevates its internal border.

67. EXTENSOR DIGITORUM LONGUS.—*Motor point:* lateral and slightly distal to that of the preceding muscle.

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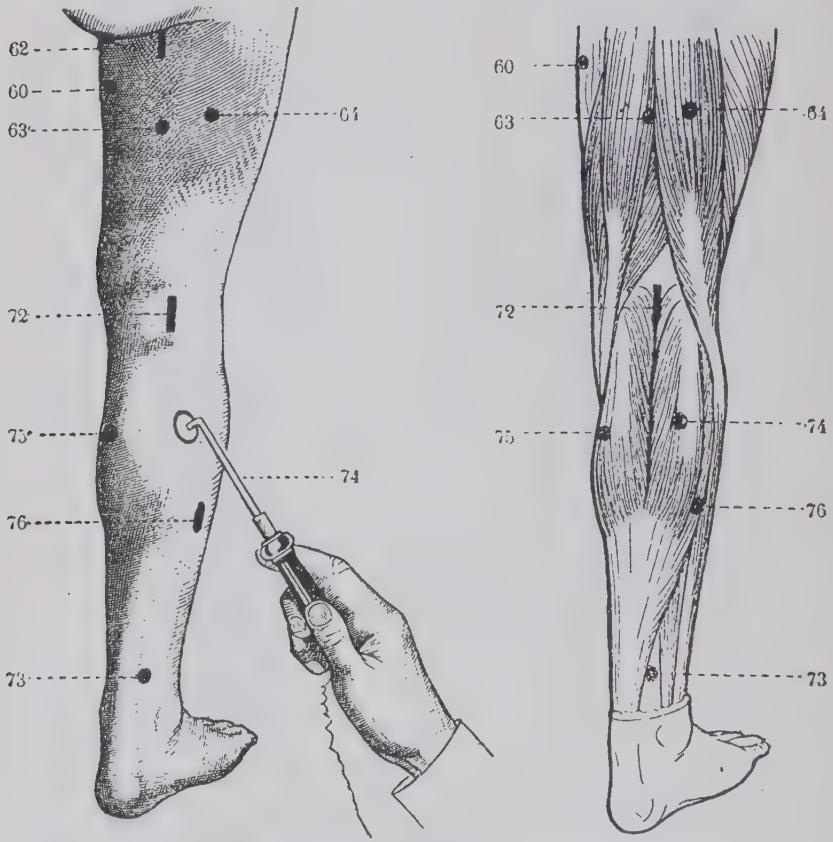
Flexes the foot and extends the first phalanges of the toes.

68. Peroneus longus.—*Motor point:* below the head of the fibula, and consequently lateral to the foregoing, but almost in the same horizontal line, or slightly above it. (It should be remembered that stimulation of this muscle lateral to its motor point often gives rise to inversion of the formula.)



Figs. 33 and 34.—Motor points of lower limb (posterior aspect).

Draws the internal border of the foot downwards and the plantar surface of the foot outwards.

69. Peroneus brevis.—*Motor point:* at the junction of the middle and lower third of the leg, in a vertical line through the preceding point.

Causes slight abduction of the foot.

70. EXTENSOR PROPRIUS HALLUCIS.—*Motor point :* between the tendons of the extensor communis and tibialis anticus, close to the crest of the tibia, in the lower third of the leg.

Extends the first phalanx of the great toe.

71. EXTENSOR BREVIS DIGITORUM.—*Motor point :* below and in front of the external malleolus.

Extends the toes.

(5) Internal Popliteal Nerve

72. **Internal Popliteal Nerve.**—*Point for stimulation :* towards the middle of the popliteal space, slightly lateral to the middle line and below the flexion fold of the skin.

Stimulation causes extension of the foot on the leg and flexion of the toes.

73. **Posterior Tibial Nerve.**—The point for this nerve is behind the instep, on the inner side, and the tendo achillis, where the plantar muscles may be stimulated. For convenience, the leg should be flexed, and the patient should lie with the lateral surface of the foot flat on the couch.

74. GASTROCNEMIUS, INNER HEAD.—*Motor point :* in the upper part of the calf, towards the internal border of the muscle.

Extends the foot on the leg.

75. GASTROCNEMIUS, OUTER HEAD.—*Motor point :* in the upper part of the calf, towards the external border of the muscle.

Same action.

76. SOLEUS.—Sometimes *accessible* on the outer and inner side of the leg, where the muscle emerges from beneath the gastrocnemius.

Extends the foot.

FLEXOR LONGUS HALLUCIS.—*Motor point :* immediately lateral to the tendo achillis, 5 or 6 cm. above the external malleolus.

FLEXOR LONGUS DIGITORUM.—*Motor point :* on the internal border of the tibia, adjacent to the internal border of the tendo achillis.

CHAPTER II

ABNORMAL ELECTRICAL REACTIONS

1. Elementary Abnormal Reactions

In a number of affections of the central and peripheral nervous system, the electrical reactions vary more or less from the normal. The study of these pathological modifications of the electrical reactions being a complex one, we shall deal in the first place with the various elementary modifications which may be encountered. We will first examine the way in which these are grouped in different pathological conditions.

These elementary modifications may be quantitative or qualitative.

1. **Quantitative Modifications.**—Evidence of diminution in excitability of a nerve or muscle by the faradic current is afforded by an appreciable increase in the strength of current required for a threshold stimulus. If, for instance, the faradic coil has to be moved up to Division 6 to give the threshold in an affected muscle, while the liminal stimulus for a normal muscle, with the same apparatus, is usually given at Division 10, diminution in faradic excitability, or

faradic hypo-excitability, may be deduced. On the other hand, if in another case an approximation of the coils corresponding to the minimal contraction in a healthy subject, causes relatively energetic contraction of a muscle, increase in excitability will be deduced, or *faradic hyper-excitability* of this muscle.

Diminution of excitability sometimes takes the form, not of requiring a stronger current in order to give the threshold, but of a reduced amplitude of the maximal contraction, as compared with a healthy muscle.

In some circumstances the diminution of excitability is such that with maximum approximation of the secondary coil, the muscle examined gives no response whatever to faradic stimulation. Contraction may then sometimes be produced by substituting a secondary coil giving a current of higher tension (finer winding). If this is ineffectual, bipolar stimulation should be tried. If, however, stimulation by the bipolar method, with the strongest high tension current which the patient can endure, causes no contraction, it may be concluded that the muscle is inexcitable by the faradic current, and that faradic excitability is abolished: this phenomenon is sometimes known as *Duchenne's reaction.*

Dubois (of Berne) has very justly observed that muscles which have been regarded as inexcitable by the strongest tetanising faradic current sometimes respond to *single induction shocks.* This peculiarity should be remembered, for although it indicates a

great diminution of excitability, it shows that the latter is not entirely absent.

With the galvanic current, according as the minimal appreciable contraction is obtained with a stronger or weaker current than in the normal state, *galvanic hypo- or hyper-excitability* of the nerve or muscle concerned will be deduced as in the preceding case.

We shall also deduce *abolition of galvanic excitability* when, in an examination conducted with each pole successively, the gradual increase of the intensity of the current within the limits of endurance gives no semblance of a contraction.

Causes of Error.—(1) Hyper-excitability may be merely *apparent* in thin subjects whose nerves and muscles are immediately beneath the skin, or in patients with such anomalies in the situation of the nerves as unusual superficiality, which renders them more accessible to stimuli.

(2) Hyper-excitability and hypo-excitability of nerves and muscles may be merely apparent, in that quantitative variations from the normal are due, not to a modification of excitability, but to *an unusually high or low degree of resistance* in the skin.

In forming conclusions as to alterations in faradic and galvanic excitability, the condition of the skin should therefore be taken into account, since the skin acts as an additional resistance in the way of the current. Variations in its conductivity cause variations in the threshold. Now, as trophic cutaneous disorders are included in the manifestations of many

affections of the central and peripheral nervous system, and since these disorders alter the resistance of the skin, it will be understood that this accounts for endless erroneous conclusions. Thus a very resistant skin may conceal increased excitability, and similarly, the coexistence of a slight hyper-excitability, with a somewhat diminished skin resistance, will simulate very pronounced hyper-excitability.

Amongst the causes which reduce skin resistance and are liable to suggest increased excitability, we should mention thinning of the stratum corneum, a moist condition of the skin, a reduction in the subcutaneous layer of fat, and all other causes by which the distance between the nerves and muscles and the electrode may be reduced. On the other hand, scleroderma, hyperkeratosis, dryness of the tissues, vaso-motor disorders, and a lowered temperature, increase the resistance; similarly, lubricants used for massage (talc or fat), which, finding their way into the glandular ducts, produce similar effects.

These alterations in the conductivity of the skin render the detection of slight modifications of excitability a matter of great delicacy.

2. **Qualitative Modifications.**—The following may be encountered:

(1) Inversion of the normal formula.
(2) Slowness of contraction.
(3) Galvanotonic contraction.
(4) Myotonic contraction.
(5) The longitudinal reaction.

Inversion of the Formula.—In the normal state, in stimulation of a nerve or muscle with the galvanic current, the production of the anodal contraction (ACC) always requires a stronger current than that necessary for producing the kathodal contraction (KCC).

In the pathological state, this relation may be modified, and the anodal contraction may be obtained with an equal or smaller number of milliamperes than that required for producing the kathodal contraction. We say, then, that there is *polar equality* (KCC = ACC) if the two contractions are first appreciable with the same number of milliamperes, and *inversion of the normal formula* (ACC > KCC), if ACC is produced with a weaker current than KCC.

The same modifications, polar equality and inversion, may appear in the relations of the opening contractions; that is to say, the formula may become AOC = KOC or KOC > AOC, in contradistinction from what is found in the normal state. In practice, however, the opening contractions are only rarely investigated, since the changes in the closing contractions usually indicate the elementary reaction of inversion with sufficient distinctness.

This *reaction of inversion* is also sometimes described as *Erb's reaction*, after the author who was the first to study it completely.

In a precise and detailed examination, the degrees of intensity corresponding respectively to the minimal contractions KCC and ACC should always be measured.

Care should be taken to note the degree of intensity determined for each muscle, thus furnishing, for the purposes of later examinations, a record useful as a basis for comparison, and to decide from this whether the inversion is becoming more pronounced, or whether, on the other hand, the anomaly is tending to disappear.

Causes of Error.—(1) It should not rashly be concluded that polar equality or inversion is present when these anomalies are observed with a current of any indefinite intensity. The experiments of Chauveau and Boudet, which we have already described, show that in animals, with increasingly strong currents, the contraction ACC becomes first equal to, and finally greater than, the KCC. This phenomenon can scarcely be demonstrated in man in the normal condition, on account of the difficulty in using currents of sufficient strength. On the other hand, this particular inversion is not infrequently observed in the pathological state. It is distinguishable from true inversion in that, contrary to the latter, it is not produced at the threshold. Whereas *in true inversion the AC contraction is given when the KC stimulus gives no response*, in inversion associated with Chauveau's phenomenon, it is merely that the *force* of the AC contraction is greater than that of the KC contraction.

Inversion at the threshold is also relatively less common, and we believe that it has a much more definite and important significance. The inversion associated with Chauveau's phenomenon may indicate

a pathological condition, or a variation of excitability, but inversion at the threshold is evidence of serious and far-reaching disorder in the structure of the muscle.

(2) Inversion is usually associated with slowing of the contraction. It may, however, be observed in the normal state, with lively contraction, in perfectly healthy muscles. Those most frequently presenting this anomaly are: supinator longus, the deltoid, the inner head of triceps, the abductor digiti quinti, and first interosseous, in the upper limb; the gluteals, the vastus internus, peroneus longus, and the gastrocnemius, in the lower limb.

Inversion of the formula in these cases results from incorrect placing of the testing electrode, its application outside the point of election, or the use of an electrode of too large dimensions relative to the muscle tested. A slight alteration in its position, by 1 cm., for instance, is often sufficient to reproduce the normal reaction.

This false inversion is easily explained by reference to Pflüger's law of the origin of stimulation.

With the electrode in a wrong position, the KC stimulus falls on a point of lower excitability than the motor point. At anodal closure, however, the stimulus from the indifferent pole arrives at the extremity of the muscle, and there creates a virtual pole which may be of high density, and may act on a more excitable region than that over which the electrode is placed.

(3) If the intensity of the threshold of KCC is noted in milliamperes, and that of the threshold of ACC immediately afterwards, equal values may be obtained, or the ACC may even be given with a lower intensity. Here again polar equality or inversion may be only apparent. The passage of the current giving the KCC, while the instrument is being read, lowers the resistance of the organism. The AC stimulus following the KC is therefore passing through a less resistant circuit, and will consequently require an equal or smaller number of milliamperes.

The anomaly disappears if the values are read only after a number of closures with each pole alternately.

(4) Examinations carried out without the help of a double key may also reveal an apparent inversion.

The passage of the current at the moment of kathodal closing produces a polarisation current in the tissues which is antagonistic to the current producing it. If this be followed rapidly by an anodal closing stimulus, the strength of the latter is increased by that of the polarisation current, and the AC contraction, produced by a current of greater intensity, becomes equal to, or more forcible than, the KC contraction.

This source of error is obviated by the use of a double key. The polarisation current is short-circuited though this instrument at the moment of release of either key (see p. 9).

Slowing of the Contraction.—It is essential in

electro-diagnosis to observe the nature of a muscular response.

The contraction, which is normally short, sharp, and of lightning rapidity, may undergo changes in form, more commonly becoming *slowed*, or definitely *slow, sluggish, and vermicular*. A more or less diffuse wave in the muscle can be observed beneath the skin, and the contraction suggests somewhat the creeping movement of an earthworm.

This anomaly was discovered by Remak.

The slowness of the contraction is sometimes difficult to detect, particularly when it is not pronounced: in such difficult cases, an indisputably healthy muscle in the same subject should be used as a means of comparison.

The slowness is almost always *more marked* in the AC contraction than in the KC. In cases where it is slight, it may even be completely absent in KCC, which remains characteristically lively, and only be evident in ACC.

In other cases, slow contractions become progressively more rapid as the examination proceeds. Such phenomena are associated with partial reaction of degeneration.

Slowness of contraction is not peculiar to galvanic excitation. It is often similarly observed in faradic excitation, when excitability to this form of current is retained.

Analysis of the slow contraction by means of the graphic method, and comparison with a normal

tracing, show that slowing occurs in all the different stages of the contraction; the latent period is lengthened, the upstroke of the shortening period is less abrupt, and the lever remains at this height for some time, whereas a normal myographic curve exhibits a sharp apex (fig. 36). Lastly, the period of relaxation is prolonged, particularly towards the end. It should be noted that it is always in this last stage, that of relaxation, that slowing is most pronounced and characteristic.

Larat's suggestion that the nature of a contraction should always be recorded in this way, is certainly attractive, since it would afford permanent records, and facilitate comparisons of great value in determining the evolution of muscular changes. Unfortunately an electro-diagnostic examination is already a lengthy process, and it is hardly to be expected that electrologists will acquiesce in a complication in technique when its purpose can always be served by a careful examination.

Causes of Error.—Sources of error in estimating rapidity of contraction will be studied in connection with the reaction of degeneration (see p. 77).

Galvanotonic Contraction.—We have seen that, in the normal state, a relatively strong current applied to a nerve causes at kathodal closure, either a single forcible contraction or a prolonged or "tetanic" contraction, which is, more correctly, called tonic. This continues while the current is passing, and ceases at the break.

This galvanotonic contraction is easily obtained by stimulation of the nerve, but almost impossible to produce over the muscle, in the normal state. But in the pathological condition it may be obtained with relatively low intensities. Erb, who first discovered this, observed that, in the reaction of degeneration, the slow contraction sometimes assumed the character of a tetanus, and continued until the circuit was broken. Since then it has frequently been observed by Huet, Delherm, Bourguignon, and by the authors.

It does not usually occur when the muscle is stimulated indirectly through the nerve, when the latter retains its excitability, but on direct stimulation of the muscle at the motor point. Sometimes it characterises the entire contraction, which is tonic from the outset. Sometimes it follows a slowly initiated contraction, which is thus succeeded, not by complete relaxation, but by a continuous state of contraction, relaxation only occurring when the circuit is broken.

In general it is more obvious with the *anodal* than with the kathodal stimulus.

It is most readily detected by stimulation *in the neighbourhood of the tendon* (longitudinal excitation), rather than at the motor point (the kathodal electrode being over the tendon).

The peculiar feature of this galvanotonic contraction is that its duration coincides with that of the current. *It ceases when the circuit is broken.* For this reason it has been called temporary galvanotonic contraction,

in distinction from permanent galvanotonic contraction, which persists after cessation of the stimulus, an important characteristic of the myotonic reaction (Thomsen's disease).

Permanent Galvanotonic Contraction differs from the preceding in that it persists after the circuit has been broken. It is produced by sufficiently strong currents with either pole at the motor point. It is most definite in AC, or better still, with longitudinal stimulation. It persists for several seconds after cessation of the stimulus, before relaxation occurs. It may disappear with repeated stimuli, which reduce its duration. It forms part of the myotonic reaction, and occurs in certain muscles at the onset of myopathies.

The Longitudinal Reaction.—In the normal state, muscles are excitable anywhere in their fleshy portion, but their excitability reaches an optimum in the small area of the motor point. Variations in excitability which occur in the muscle in a pathological condition, and become evident on stimulation of the motor point by the unipolar method, are not confined to this point, but affect the entire muscle. Thus the distal extremity of an affected muscle responds more readily than in the normal condition. Whereas a strong galvanic current is required for producing contraction in a healthy muscle by stimulation at the junction with its tendon, a relatively weak current may suffice for this if disease is present. When at the same time excitability at the motor point is

markedly reduced, or even absent, stimulation at the junction with the tendon will be found more effective, and may even entirely replace excitability at the motor point.

Discovered by Remak (1876), again by Doumer in 1891, and studied shortly afterwards by Huet (1894), this phenomenon was described by Wertheim-Salomonson as displacement of the motor point.

Later, Ghilarducci, having shown that it could be obtained by stimulation below the muscle, even, indeed, at the extremity of the limb, named it the remote reaction of degeneration, an expression which was used for some time, but is to-day almost universally replaced by the terms longitudinal hyper-excitability, or longitudinal reaction, the name given to it by Huet.

Longitudinal reaction or hyper-excitability, displacement of the motor point, and remote reaction of degeneration are therefore different names for the same phenomenon. In symbols it is often written RDd.

It has long been regarded as a late or terminal manifestation of the reaction of degeneration, but it is now well established that it accompanies the latter throughout its development, and constitutes one of the earliest and most important elementary reactions (sometimes appearing two or three days after injury to the nerve).

When the testing electrode is applied to the lower extremity of the belly of a muscle which is degenerating,

at a short interval after the commencement of this process (fig. 35), it is observed that the closing stimulus at this point causes contraction with a much weaker current than would be effective in the normal state. Longitudinal hyper-excitability is present; and this hyper-excitability is actual, and *absolute*. Later, excitability diminishes at the motor point, and diminishes equally to longitudinal stimulation, a stronger current being required than in the normal state. But the diminution in excitability being less to longitudinal stimulation than at the motor point, longitudinal stimulation continues more effective than stimulation at the motor point; hence there is *relative* longitudinal hyper-excitability.

FIG. 35.—Examination of the longitudinal reaction on the tibialis anticus muscle.

When excitability at the motor point is abolished, excitability at the point of junction with the tendon may be the only evidence of excitability in the muscle.

The contraction following longitudinal stimulation is a manifestation of degeneration, and possesses the

essential characteristic of degeneration phenomena, which is *slowness*. This feature is often even more pronounced on longitudinal stimulation than at the point of election. The contraction produced by stimulation of the motor point may even seem lively, or its nature may appear doubtful, but its sluggish nature will usually be obvious on stimulation in the region of the tendon.

The order of appearance of contractions in longitudinal stimulation does not differ from the normal order, at least in the majority of cases; KCC is obtained as a rule before ACC, but inversion occasionally occurs.

In the initial phases only, of the reaction of degeneration, a galvanotonic, instead of a slow, contraction, is sometimes obtained. The other reactions of the muscle are usually perfectly normal at this stage; stimulation at the motor point gives no slowed contraction, and shows no modification of the formula. It follows that the independent occurrence of a tonic contraction in longitudinal examination may be a very early and delicate sign of a change in the muscle (Bourguignon).

Rich's Reaction, or the Reaction of Compression.—The reaction of Rich, or, more exactly, of Richard Geigel, is a quantitative reaction following compression of the nerves and vessels with the fingers, or with Esmarch's bandage. It is characterised by the early appearance of the opening contractions on stimulation of the nerve.

Supposing that in the normal state the succession of contractions is obtained with the following intensities:

KCC	1 ma.
ACC	2 ma.

AOC	3 ma.
KOC	10 ma.

After compression with the fingers or Esmarch's bandage they are obtained as follows :

KCC	1 ma.
ACC	1 ma.
AOC	2 ma.
KOC	2½ ma.

It will be seen from this that the intensities required for obtaining the opening contractions, particularly KOC, are very low in comparison with the normal.

The explanation of the phenomenon probably lies in the fact of existence of a polarisation current, which is superimposed on the principal current at the break, and is of unusual strength because the products of electrolysis, which are the cause of polarisation, cannot be carried away by the blood-stream on account of the compression.

The phenomenon becomes more marked the longer the current is kept closed, which would appear to verify this theory.

II. Grouping of the Elementary Reactions

In nervous pathology, when the responses of nerves and muscles to electrical stimulation vary from the normal, the anomaly may consist solely in an increase or reduction of excitability ; such a modification is purely quantitative. In other cases the anomaly is characterised both by quantitative modifications and by a change in the form of the muscular contraction, which may or may not be associated with an alteration of the normal order of appearance of the contractions.

The reaction of degeneration falls in the last category.

Normal Reactions.—Normal excitability is pre-

served (or, to be less dogmatic, only varies slightly) in the following:

1. Affections, slight or even serious, of the brain and spinal cord (epilepsy, tabes, chorea, paralysis agitans, cerebral concussion, etc., etc.).

2. Affections of the peripheral motor neurone, liable to give rise to the reaction of degeneration, but failing to do so owing to the mild nature of the morbid process.

3. Affections of the neuro-muscular system of a functional nature. The motor paralyses of hysteria show no modifications in the electrical reactions. Sometimes, however, slight hypo-excitability is observed in hysterical subjects. In certain cases this is merely apparent, resulting from the increase in skin resistance which frequently occurs in hysteria; in other cases the muscles are found to be in a spastic condition, and it is supposed that a stronger current is required to give the threshold in spastic muscles than in a normal subject, whose muscles are completely relaxed.

III. Increased Excitability

Increased excitability is characterised by the appearance of the threshold with weaker currents than in the normal state.

If only slight it is not easily detected, and its existence may remain uncertain. In bilateral affections, the only means of comparison is with the usual values of the faradic and galvanic threshold in

the healthy subject, but in the case of a unilateral lesion, there is no possibility of doubt unless the differences in excitability between the two sides are only extremely slight.

An increase in excitability occurs in recent organic cerebral paralyses, particularly if these are accompanied by spasticity; in certain forms of myelitis, in the first stage of tabes, disseminate sclerosis, Little's syndrome, tetany, writer's cramp, reflex contractures, and in a general way in the majority of affections in which the tendon reflexes are exaggerated.

IV. Reduced Excitability

Simple diminution of excitability is commoner than augmentation. It is recognised when the threshold stimulus, with both forms of current, requires a greater strength of current than in the normal state.

As with hyper-excitability, slight degrees of it are sometimes difficult to detect.

Sometimes it is more marked with one of the forms of current than with the other, either with the faradic, or with the galvanic.

Lastly, it is often more marked on stimulation of nerves than of the muscles.

In certain cases the diminution in excitability of the nerves is such that with ordinary electro-diagnosis apparatus, using the bipolar method, no response

whatever can be obtained; excitability may then be considered abolished.

Sometimes, in severe reflex atrophies or myopathies, for instance, the loss of contractile substance in the muscle may be so extensive that the muscle will not respond to electrical excitation: in such a case the excitability of the muscle is abolished.

Simple hypo-excitability is observed in nerves and muscles in old cerebral paralysis and in anterior poliomyelitis, but then only in muscles slightly affected, and capable of rapid regeneration; in hæmatomyelitis, reflex muscular atrophies or atrophy due to functional inactivity; in therapeutic immobilisation, the voluntary immobilisation of malingerers, or the unconscious immobilisation of hysterical subjects, but in these cases it exists only in a slight degree: it is always more pronounced when it corresponds to an atrophy following a fracture or articular lesions. It is the rule in myopathies, in certain slight peripheral paralyses, benign facial palsy *a frigore*, the majority of peripheral paralyses by slight temporary compression, etc.

Primary myopathies are accompanied by a hypo-excitability which increases in degree as the atrophy becomes more advanced. In the early stages, when the amyotrophia is still only slightly perceptible, the diminution in excitability takes the form, not so much of a raised threshold as of a reduced amplitude of contraction (Huet).

In infective or toxic neuritis (alcoholic and diph-

theritic paralyses, etc.), simple hypo-excitability justifies a favourable prognosis.

Hypo-excitability also appears in traumatic peripheral neuritis, infective or toxic neuritis, at a late stage of their development, following after the reaction of degeneration. At this period the power of voluntary movement may have been wholly, or only partially, recovered.

In cases which have not been cured, *i.e.* in which the power of voluntary movement has not been regained, excitability is always greatly diminished. Usually only traces of it persist.

Cases of Extreme Hypo-excitability. — Very profound hypo-excitability, sometimes even so profound that no faradic response is obtained, and no galvanic current of less than 20, 25, or 30 milliamperes will excite contraction, is sometimes met with in certain acute processes with severe clinical symptoms, such as cerebro-spinal meningitis, poliomyelitis, certain forms of toxic or infective neuritis, traumatic neuroses, and nerve compressions (Huet).

Sometimes the whole area affected shows this hypo-excitability; at other times muscles or other nerves in the immediate neighbourhood definitely show the reaction of degeneration.

A peculiarity of these cases is that, in spite of the severity of clinical signs which suggest the existence of RD (severe compression, for instance), nothing is found beyond hypo-excitability. It is then discovered that with this marked hypo-excitability, bordering on

inexcitability, and often characterised by complete loss of faradic excitability, the galvanic contraction, which might well be expected to be slowed, is still brisk.

It might also be supposed that this hypo-excitability represents the last stage in the course of a reaction of degeneration, not previously recognised, owing to its rapid development, but this is by no means the case, since excitability diminishes *very rapidly from the onset of the affection.*

However this may be, experience shows that in these cases where serious clinical signs are associated with a hypo-excitability of disquieting severity, *the prognosis is relatively favourable*, and recovery is readily brought about.

When, in a region showing RD are found muscles exhibiting this symptom of pronounced hypo-excitability, it is invariably in the latter that the power of voluntary movement is regained more rapidly and completely.

According to Huet, marked hypo-excitability is commonest in the lower limb, in the muscles of the thigh, more particularly the biceps and vastus internus, and in the posterior muscles of the leg, particularly the gastrocnemius.

V. The Reaction of Degeneration

By the reaction of degeneration (RD) is understood a syndrome composed of the following elementary electrical reactions :

1. The excitability of the nerve (faradic and galvanic) is abolished.

2. The faradic excitability of the muscle is abolished.

3. The galvanic excitability of the muscle is either increased or diminished.

4. The following qualitative changes, on galvanic stimulation of the muscle, are present:

(*a*) Slow or galvanotonic contraction.

(*b*) Inversion of the formula (ACC > KCC), or polar equality (ACC = KCC), or the normal formula KCC > ACC.

(*c*) Longitudinal hyper-excitability.

When these modifications are coexistent and definite, *the reaction of degeneration* is said to be *complete*.

When a motor nerve in an animal is divided, changes in the electrical reactions of the nerve and the muscle appear, usually on the second day, develop for several weeks, and at a certain stage in this development give the picture of complete RD. Hence, certain authors have proposed to distinguish complete RD by the term "syndrome of nerve section."

The expression "reaction of degeneration" originates in the fact that this electrical syndrome appears when a nerve undergoes Wallerian degeneration.

This parallelism is not, however, admitted by all authors. Strumpell, for instance, was unable to detect any degenerative lesion, apart from proliferation of the nuclei, in excised muscles showing all the characters of RD, and disputes the degenerative significance attributed to the reaction of degeneration, explaining it simply as a reaction on the part of the muscle itself when deprived of its nerve supply.

Similarly, Babinski, taking account of the fact that the characters of RD may appear extremely early, at a period when the muscle cannot have undergone morphological change, three or four days after section of the facial nerve, for instance, regards the reaction

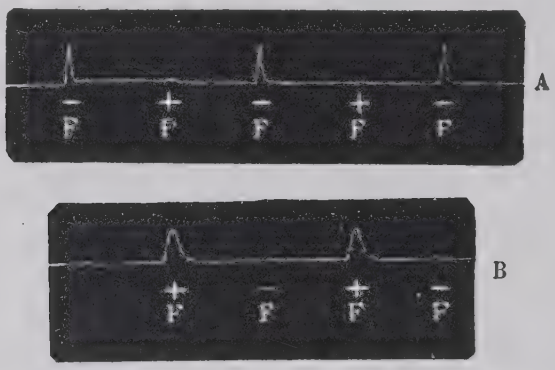


FIG. 36.—Diagrammatic representation of muscular responses to galvanic stimulation (closing contractions).

(A) Normal muscle.—At $\bar{F}$ (kathodal closure) the contraction is brisk, and more forcible than at F (anodal closure).

(B) Muscle showing the reaction of degeneration (with inversion of the formula).

At $\dot{F}$, anodal closure gives a slow contraction, more forcible than that produced at $\bar{F}$ (kathodal closure).

of degeneration as the response of a muscle released from the control of the nervous system.[1]

[1] Pitres has shown that the slowing of the muscular contraction obtained by percussion, in peripheral nerve lesions, coincides with disappearance of faradic excitability in the muscles. He therefore advised clinicians with no electro-diagnosis apparatus at their disposal to resort to percussion as a substitute, regarding slow contraction on percussion as adequate evidence of RD. That this is a mistake is clearly shown by the slowed contraction obtained on percussion in reflex paralysis (Babinski, Hallion, and Froment, "Slowed muscular contraction obtained by percussion, and its clinical significance, studied by the graphic method," *Soc. Neurol.*, June 29th, 1916).

Partial Reaction of Degeneration.—The reaction of degeneration does not always appear in the form which we have just described. Frequently the quantitative modifications exist only in a slighter degree; the nerve has not entirely lost its excitability, but only shows diminution in faradic and galvanic excitability to a greater or less extent; similarly, the muscle may still respond to more or less vigorous faradic stimuli. The other features of RD are, however, identical.

In brief, partial reaction of degeneration is constituted by the following elementary reactions:

1. The excitability of the nerve (faradic and galvanic) is more or less diminished.

2. The faradic excitability of the muscle is more or less diminished.

3. The galvanic excitability of the muscle is either increased or diminished.

4. The following qualitative changes appear in the muscle on galvanic stimulation:

(*a*) Slow or galvanotonic contraction.

(*b*) Inversion of the formula (ACC > KCC), polar equality (ACC = KCC), or the normal formula (KCC > ACC).

(*c*) Longitudinal hyper-excitability.

In certain cases the diminution in faradic excitability may be very slight or even imperceptible, the KC contraction may remain brisk, and slowing only appear in ACC, or even only on longitudinal excitation. When this milder combination is present, it is said that there are *traces of the reaction of degeneration.*

Symptomatic Value of the Slow Contraction and Inversion.—Complete and partial reaction of degeneration consist, therefore in an association of certain elementary reactions, and not, as is still sometimes said, merely in inversion of the galvanic formula. Of all the elementary reactions which together constitute the syndrome of degeneration, inversion of the formula is actually *the least constant*, always provided that it is tested for *with liminal stimuli*, and not with stronger currents. At the threshold, inversion is relatively uncommon.

The contrary applies to *the slow contraction, or its equivalent, galvanotonic contraction, which is in some sense pathognomonic of RD.* If slowed contraction or galvanotonic contraction is absent, RD is not present.

In one variety of the condition, it is true, slowing is absent, but this absence is only apparent. This occurs when, as in certain chronic affections in which the degenerative process, instead of attacking the peripheral motor neurone as a whole, gradually affects one motor cell after another, or one nerve fibre after another, the reactions of the altered muscle fibres are masked by those of the fibres which are still healthy. In this way the slow contraction is concealed by the brisk contraction of the unaffected fasciculi, and only a more or less marked simple hypo-excitability is detected. Later, when the fasciculi originally immune are affected in their turn, the fasciculi originally attacked have become almost inexcitable ; hence there

is marked hypo-excitability of the whole muscle, which militates against satisfactory detection of the qualitative changes characterising RD (Huet). It should be added that slowed contraction can be observed in cases of this kind in superficially situated muscles, a contraction which, however, is briskly initiated, a fact for which the coexistence of healthy and degenerated fibres is an obvious explanation.

The slow contraction is usually observed only on direct stimulation of the muscle. Thus in partial RD, in which the nerve is still excitable, direct galvanic stimulation of the muscle gives the slow contraction, whereas stimulation of the nerve (galvanic or faradic) gives a brisk contraction, and no polar inversion.

We shall see later, however, that slowing may sometimes be shown on excitation of the nerve (Remak's faradic reaction of degeneration).

Causes of Error.—There can be no doubt,—and this point has recently been strongly emphasised,—that slowness of the contraction may exist apart from the reaction of degeneration.

Experimentally, in the frog, modifications in the form of the normal contraction have been obtained by the use of various substances—caffeine, quinine, veratrine, and salts of potassium and ammonium. Cluzet observed slowing of the contraction after the injection of spartein.

Curare acts in the same way, causing temporary paralysis of the motor nerve fibres; the muscle becomes almost insensible to induction shocks (Brücke); its galvanic excitability remains almost normal, but the contraction is slowed (Cluzet). When the effect of curare passes off, the electrical reactions become normal.

Clinically, in man, in certain general affections

associated with cachexia, such as diabetes, jaundice,[1] the cachexia of new growth, and tuberculosis,[2] a certain *prolongation of the contraction* is sometimes seen.

Further, exhaustion from excessive faradic stimulation (Dubois), CO_2 poisoning, and cold, may cause slowing.

The effect of cooling on muscular contraction in the frog and other cold-blooded animals was recognised long ago by Helmholz, Pflüger, Marey, and others. In warm-blooded animals, prolongation of the contraction following a reduction of temperature appears, on the contrary, to have been less closely studied. Bernhardt, however, and Hitzig, have drawn attention to a prolongation of the faradic contraction, and others have subsequently demonstrated clearly that a contraction, slowed by cold, recovers its rapidity when the muscle is warmed.[3]

Grund[4] was the first to speak of a "reaction of cooling," and to attempt to distinguish it from the reaction of degeneration.

Since faradic excitability is preserved, the reaction of cooling might simulate partial reaction of degeneration, and this would explain how authors have been able to discover RD in affections in which it does not occur. In this way Bernhardt imagined that he had detected RD in a case of Raynaud's disease.

The pseudo reaction of degeneration *a frigore* is

[1] Edinger, *Zeitschr. f. Klin. Med.*, 1883.

[2] Reiss, *Die elektr. Entartungsreaction*, Berlin, 1911.

[3] Graphic records show that there is no increase in the latent period, but a prolonged phase of contraction, an interval, and slow relaxation.

[4] Grund, *Zentralblatt f. Neur.*, 1908, et *Deuts. Zeits f. Nervenheilkunde*, 1908, p. 172.

sometimes associated with polar equality, or with inversion. Sometimes the slowness of the contraction is as marked as in the most pronounced RD. Prolongation of the contraction is particularly evident in slender muscles, more especially the small muscles of the extremities. But with a considerable lowering of temperature, the phenomenon may appear in the larger muscles.

According to Reinecke,[1] excitability shows some slight modifications; it is slightly increased in both muscle and nerve to the galvanic and faradic tetanising currents, but diminished to single shocks. These changes are more evident in stimulation of the nerve.

The distinguishing point from partial RD is the immediate disappearance of the slowing on warming or exercise.

A slowed contraction may be produced, not only by the action of external cold, but by *hypothermia* of the limb from vaso-motor disturbance. It seems probable that the phenomenon results from asphyxia of the muscle by the accumulation of CO_2.

In reflex paralyses, slowed contraction appears when vaso-motor disturbance is present; rapidity of contraction is decidedly regained, and may even become normal on the application of heat or by removal of the exciting cause.

The cooling of a dead body acts in the same way. Babinski, on the one hand, and Marie and Cluzet, observed slowed contraction, with polar inversion and faradic inexcitability, one hour

[1] Reinecke, *Zeitsch. f. allg. phys.*, 1908, p. 422.

after death. Cut off from indirect stimulation through the motor nerve, the death of the latter being is a more rapid process, the muscle would thus react in accordance with its own properties of excitability (Babinski).

External cold and lack of oxygen may also affect faradic excitability in the limbs. Faradic slowing, however, is not always as obvious to the eye as galvanic slowing, but it may be detected by determining the number of stimuli (per second) required to produce tetanus. The number is invariably lower than the normal, *i.e.* there is *premature fusion of the contractions.* In practice this effect gives rise to great difficulty when a patient for examination, with a peripheral paralysis, is also suffering from vaso-motor disorder and hypothermia.

Similarly, these effects should be taken into consideration during very cold weather, as we had reason to know during the severe winter of 1917. Numerous mistakes in electro-diagnosis were made. Reflex paralyses, or even psychic paralyses associated with slowed contraction, were described and put down as reaction of degeneration, mistakes in diagnosis which might easily have been avoided, either through observing that the same slow contraction was given in regions where there was no question of a nerve lesion, or by adequate warming of the limb examined.

From the fact that cold may cause slowing of the contraction, it does not follow that this sign should never be regarded as a valid indication of the reaction of degeneration. It is perhaps necessary, in order that it may continue to be regarded as pathognomonic

of RD, to specify the conditions in which it is valid; the following words might accordingly be added to its definition: "and at the normal temperature of the body," thereby paraphrasing the words, "and at the same temperature," found in the laws of physics and chemistry.

Intermediate States between the Complete and Partial Reactions of Degeneration. — 1. *The preservation of excitability to single induction shocks.*—The abolition of faradic excitability in the muscle usually refers to the rapidly interrupted faradic current. At the same time it is not uncommon to find absolute inexcitability to this form of faradic current when the muscle still responds fairly well to isolated induction shocks (Dubois[1]). Certainly the strength of the latter must be adequate, and the maximum is usually required for producing any response. The muscle responds to these single induction shocks by a sluggish contraction, not, however, exhibiting the slowness characteristic of galvanic stimulation, but none the less apparent, and readily verified by the reduction of the number of the stimuli necessary to cause tetanus.

This peculiarity of excitability in the muscle should be remembered. It shows that faradic inexcitability cannot be deduced until it has been shown, by the bipolar method, that there is no reaction whatever either to the tetanising current, or to single induction shocks.

2. *The Latent Faradic Reaction.*—Babinski, Del-

[1] Dubois, *Korrespondenzbl. f. Schw. Aertzte*, 1888.

herm, and Jarcowski[1] have shown that in certain cases of complete RD, the faradic excitability of the muscles may reappear if a continuous galvanic current be passed through the limb, while the faradic reactions are being tested. They have not, however, succeeded in re-establishing faradic excitability in the nerve.

This phenomenon, described by these authors under the name of "latent faradic excitability," indicates a less serious condition of the muscle than does complete abolition of faradic excitability, and should lead to a less unfavourable prognosis than in the case of complete RD.

This return of faradic excitability under the influence of a continuous current appears comparable to the phenomena of resensitisation of a degenerated muscle by certain chemical substances. Salts of sodium and potassium, for instance, and veratrine, which have little action on normal muscular tissue, appear, on the other hand, to exert very profound effects on a muscle which has degenerated. Muscles not previously responding to faradic stimulus become excitable by this form of current under the influence of these bodies, possibly, as Mlle. Joteyko suggests, owing to their selective action on the sarcoplasm, which they render sensitive. Whatever explanation is accepted, it is probable that the passage of the continuous current through the muscle exercises on

[1] Babinski, Delherm, and Jarcowski, *Soc. fr. d'Électroth.*, March 1912.

the latter its electrolytic effects. The chemical substances produced increase its excitability, and thus enable it to respond to the faradic stimulus.

3. *The Faradic Reaction of Degeneration.*—We have shown above that in partial RD, stimulation of the nerve (either faradic or galvanic) usually produces a brisk contraction, whereas direct galvanic stimulation of the muscle provokes a slow contraction.

In certain processes, however, a muscle stimulated with the faradic current, directly on its motor point, or indirectly through the nerve, responds by a more or less slow contraction. Slow contractions with both galvanic and faradic currents are therefore associated. Remak distinguished this combination by the name "faradic reaction of degeneration." If the nerve has lost all faradic excitability, and the muscle has retained it, a slow contraction following faradic stimulation of the muscle is sufficient to characterise the faradic reaction of degeneration.

Nevertheless this reaction has no special diagnostic or prognostic significance, and does not call for separate consideration : it constitutes one of the many guises which partial RD may assume, and merely indicates a more profound change in the muscle than partial RD with a brisk faradic response.

VI. The Evolution of the Reaction of Degeneration

The elementary reactions which together constitute the reaction of degeneration, *characterise its stage of*

maturity. This period is preceded by one of initial development, of short or long duration, according as the pathological process producing it is acute, sub-acute, or chronic. It is followed, on the other hand, by a terminal phase, which varies in nature according as the progress of the affection which caused it allows recovery or permanent inexcitability (progressive or regressive changes). The reaction of degeneration, such as we have defined it, is therefore not a fixed, lasting, and definite syndrome, but merely *a transitory and passing manifestation.*

Initial Period.—For some hours following experimental section of a nerve, an increase in both faradic and galvanic excitability is observed in the peripheral end of that nerve. This phase of initial hyper-excitability is very brief, lasting usually not more than about forty-eight hours, and is followed rapidly by a progressive diminution of excitability, which terminates towards the end of the first week in absolute inexcitability. This initial hyper-excitability probably also exists clinically, but since very early examinations are rarely carried out, this occurrence generally escapes observation, and the first condition to be detected is *inexcitability of the nerve.* Meanwhile *the faradic excitability of the muscles diminishes* more or less rapidly during the hours following division of the nerve, and disappears towards the second week.

Galvanic excitability, after a stage of diminution, which is usually very brief, becomes greater than normal, *i.e.* we have galvanic hyper-excitability; and

it was precisely this combination of galvanic hyper-excitability and decreased faradic excitability of the muscle that astonished the first observers who obtained these reactions clinically (Baierlacher, Ziemssen, and Erb).

The duration of the phase of galvanic hyper-excitability varies considerably; in certain circumstances it is very short, and is rapidly succeeded by diminution in galvanic excitability; in other cases it is very prolonged, and continues beyond the initial period, hyper-excitability being still evident at the period of established RD.

At this stage of hyper-excitability the opening contractions, particularly KOC, are sometimes obtained more readily than usual (Lugard). This peculiarity recalls what is observed in nerve compression (Richard Geigel's reaction)[1]; but here we are concerned with a reaction proper to the muscle, and not to the nerve. The appearance of opening contractions in a muscle is always, therefore, in view of the difficulty of obtaining them in the normal state, a somewhat suspicious sign. Hyper-excitability to opening stimuli, like galvanic hyper-excitability itself, except in facial paralysis *a frigore*, is merely transitory.

Along with these quantitative modifications, the following qualitative modifications progressively develop: longitudinal hyper-excitability, slowing of the contraction, and anomalies in the order of appearance of the contractions. The latter, however, is a

[1] See p. 66.

relatively late sign, and never appears before the second week.

Stage of Maturity.—This period is defined by the classical syndrome which we have analysed in detail. No further description is necessary.

Progressive Changes.—The progressive changes of RD are concerned solely with the galvanic excitability of the muscle, since both nerve and muscle have permanently lost their faradic excitability, and the nerve its galvanic excitability.

A common phenomenon of secondary importance is a more pronounced slowing of the contraction; the effect of the positive pole also usually comes to preponderate.

The essential phenomenon is progressive diminution in the galvanic excitability of the muscle. The strength of current required for obtaining the threshold becomes continually greater, and finally, *it may be long after the onset of the affection* (*from several months to one or even two years*), galvanic excitability at the motor point disappears completely.

When excitability at the motor point has been lost, the muscle may still be made to contract by a stimulus applied at a distance from its motor point, and the further period during which it continues to react to longitudinal excitation may also be prolonged for many months.

Loss of excitability at the lower extremity of the muscle does not, however, mean that the muscle has become totally inexcitable. It is, in fact, possible, by

localising the galvanic stimulus, as in localised faradisation, to obtain evidence of electrical contractility. The extensors of the forearm, for instance, when absolutely inexcitable by the galvanic current with the indifferent electrode applied on the back, will respond with very definite slow contractions, on stimulation, whether remote or at the motor point, if the indifferent electrode be applied over the lower part of the triceps brachialis, above the olecranon.

The successive periods of change in the electrical reactions which have been described, initial period, reaction of degeneration properly so-called, and the phase of DRd only, represent the course of complete RD in its entirety. Such, in fact, is the succession of effects always associated with an anatomical process producing the definite lesions of Wallerian degeneration.

It occurs after division of a nerve, and in all affections in which severance of connection with the trophic centres gives rise to lesions of the same order and the same degree. In other conditions, however, RD does not necessarily pass through all these stages. The process of its development may cease at any time, and recovery commence, if and when the histological changes underlying the condition are arrested.

Regressive Changes.—Regressive evolution is characterised by a tendency on the part of the pathological reactions to approach more nearly to the normal.

In the majority of cases this return of the reactions towards the normal is *preceded for a long or short period by a return of the power of voluntary movement.*

In lead paralysis of the extensors, for instance, the patient may entirely have recovered the use of the limb at a time when electrical examination still reveals the existence of RD.

The first sign of regression is, usually, reappearance of the excitability of the nerve. The nerve begins to react to galvanic stimulation, and then to the faradic current, the reaction to *single induction shocks* being the first to appear. In this way a brisk muscular contraction is produced, whereas faradic excitation of the muscle is still without effect, and the galvanic current gives a slow contraction. The muscle then regains its faradic excitability, at first only partially, and less completely than the nerve, while the galvanic contraction, on the other hand, is gradually losing its characteristic of slowness, and excitability is *moving upwards* towards the region of the motor point. The longitudinal reaction ceases to predominate over the reaction at the motor point, and KCC becomes equal to, and finally greater than, ACC.

This process, which is always a matter of months, invariably indicates anatomical repair.

It should be borne in mind that long after complete clinical recovery, particularly in cases where the affection has been considerably prolonged, traces of the disorder, in the form of a few definite signs, may still be present.

Inversion, for instance, may persist for a long time, either as complete inversion or as polar equality, and signs of longitudinal hyper-excitability may still

be found in muscles previously involved, several months or even years after the disappearance of RD. Lastly, quite the commonest sign to persist is *a simple diminution of excitability* in both nerves and muscles, less marked, however, in the nerves, which regain almost their normal degree of excitability, than in the muscles, the excitability of which continues very diminished for a considerable length of time, more particularly for the galvanic current.

Acute, Subacute, and Chronic Development of RD.— In certain affections, RD passes rapidly through its different phases, and arrives at the terminal stage in a few weeks. The process of development may then be regarded as *acute* (anterior poliomyelitis, section of a nerve).

As would naturally be supposed, the process is less rapid when a tumour or cicatricial tissue exercises a gradual compression on the nerves, nerve-roots, or anterior horns of the spinal cord. Sometimes the process is *subacute*, and sometimes it is slow, or *chronic*.

In traumatic nerve lesions, the acute development of RD, that is to say, its rapid initiation after the injury, is always suspicious; it always indicates severe injury to the nerve, and the probability is that actual section has occurred. At the same time, acute signs may follow simple trauma of the nerve (violent contusion), severe compression by a fragment of bone, or by a hæmatoma, or purulent infiltration.

The subacute development of RD in gun-shot

wounds is generally associated with permanent compression, continued or progressive.

The involvement of a nerve in a mass of scar-tissue, the development of an intrafascicular neuroma, and enclosure in a callus, all give rise to a slow development. For several weeks there is partial RD, which is not, however, always a favourable sign in cases of this kind. As a rule it is merely a stage preparatory to complete RD, into which it will merge insensibly.

Nothing is more deceptive than a case exhibiting partial RD which does not recover within a comparatively short time. Complete paralysis with partial RD may sometimes involve a given region, and after a few weeks the paralysis may completely, or almost completely, disappear, while the signs of RD, on the contrary, persist. After some time, and for no apparent reason, the paralysis gradually reappears in that region. This course of events is usually a sign of inflammatory compression followed by fibrous contraction.

In infective or toxic neuritis, the progress of RD is closely connected with the progress of these affections.

In chronic affections of the spinal cord or its meninges, which effect slow changes in the motor nuclei, or compress the spinal nerve-roots (chronic poliomyelitis, syringomyelia, lateral sclerosis, or any form of chronic meningo-myelitis), its development is more or less slow and gradual.

VII. Clinical Significance of the Reaction of Degeneration

Diagnostic Significance.—The reaction of degeneration only appears when a pathological process affects the *peripheral motor neurone or its cellulifugal continuation* (fig. 37); that is to say, the anterior horn cells in the cord (*poliomyelitis*, etc.), their prolongations into the medulla (bulbar motor nuclei: *labio-glosso-laryngeal paralysis*), the motor nerve-roots (*radicular paralyses*), or the peripheral motor neurone (*traumatic changes: section, compression*, etc.; forms of *neuritis*).

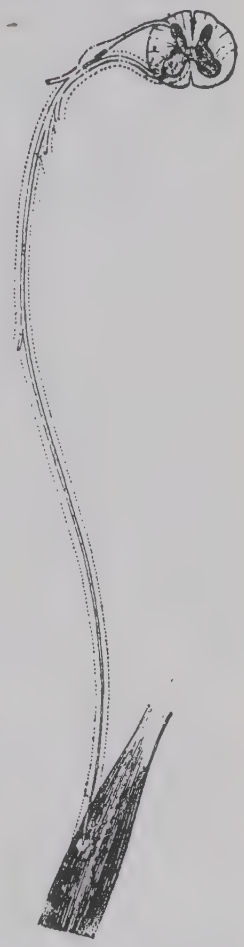


Fig. 37.—Topography of RD. The dotted line encloses the peripheral motor neurone.

Any pathological process not calculated, by its anatomical situation, to affect the peripheral motor neurone, *never* gives rise to the reaction of degeneration. The reaction never accompanies brain lesions, primary affections of the muscles (myopathies, reflex atrophies), or myelopathies localised in the white matter or the posterior horns. Nevertheless RD may appear in the latter if the anatomical change simultaneously affects

the peripheral motor neurone at any point, or attacks it secondarily (as in amyotrophic lateral sclerosis, syringomyelia, and hæmatomyelia).

The existence of the reaction of degeneration in any given case, therefore, introduces *an element of certainty* in the problem of diagnosis, by immediately excluding a number of diseases, and by limiting investigation to the pathological conditions, the site of which correspond to its distribution.

Its absence, however, *does not exclude these possibilities*; because the reaction of degeneration has not been detected, it should not be concluded that the peripheral motor neurone is not involved in the seat of the affection. Poliomyelitis or neuritis, for instance, if their anatomical effects are not far-reaching, may give rise merely to quantitative modifications of electrical excitability, and not, therefore, to RD.

PRINCIPAL AFFECTIONS OF THE NERVOUS SYSTEM IN WHICH RD APPEARS

Brain

Changes in the bulbar nuclei	Labio-glosso-laryngeal paralysis. Areas of softening. Tumours.

Spinal Cord

Lesions of the anterior horns	*Acute processes*	Infantile paralysis. Acute anterior poliomyelitis in the adult.
	Chronic processes	Forms of chronic poliomyelitis (of the Aran-Duchenne type, etc.).
Lesions invading the anterior horns		Amyotrophic lateral sclerosis. Syringomyelia. Hæmatomyelia.

Compressions at the point of exit of the nerve roots or on their course within the vertebral canal	Pachymeningitis. Tumours. Fractures and dislocations.
Inflammatory lesions of the spinal nerve-roots	Radiculitis in cerebro-spinal meningitis, etc.

Peripheral Nerves (Roots, Trunks, and Branches)

Traumatic changes	By division, compression, stretching, etc.
Infective neuritis (*localised or multiple*)	In typhoid, syphilis, gonorrhœa, scarlet fever, influenza, diphtheria, tuberculosis, etc.
Toxic and dyscrasic neuritis (*localised or multiple*)	In poisoning by alcohol, lead, and carbon bisulphide, and in diabetes, etc.
Neuritis *a frigore*	Facial paralysis, radial paralysis, etc.

The topographical data afforded by the existence of RD are of the greatest value in establishing or verifying a differential diagnosis.

Its presence during the course of a motor paralysis is absolute proof that this paralysis is not consequent on a lesion of the cortex or of the corona radiata, and is neither hysterical nor simulated. Nor does RD occur in the course of muscular atrophy. The possibility of either reflex or myopathic muscular atrophy may also therefore be eliminated at once.

But although RD enables us to localise the anatomical seat of an affection to the peripheral motor neurone, there is nothing in the syndrome itself to suggest *what part of the neurone* is involved, or in other words, whether the pathological process is located in the cord, the nerve-roots, or the trunk of the pheripheral nerve.

In this connection, however, its muscular distribution may be of some limited value. If, for instance, RD is found in practically the same degree throughout the region innervated by a single nerve, peripheral neuritis may be deduced. If it should be localised to muscles belonging to one radicular group, and cannot be detected in any other muscle, it would be reasonable to suggest a lesion of the anterior horns, or a radicular paralysis.

Significance in Prognosis.—The degree of RD (complete, partial, or traces of RD) is not a " measure " of the gravity of any given case, or a reliable guide in prognosis, *except by comparison with other cases of the same nature.* Thus the muscles of the antero-external region of the leg may be affected in the same degree (by complete RD, for instance) in one case by poliomyelitis, and in another by influenzal neuritis. Notwithstanding the equal degree of RD in the two cases, the prognosis is essentially different, since in the first case recovery is doubtful, but, on the contrary, highly probable in the second.

Similarly, partial RD, which is a favourable sign in facial paralysis *a frigore*, suggests a grave prognosis when it appears in the course of a medullary affection (poliomyelitis or syringomyelia).

With an equal degree of RD, the outlook is often more unfavourable in the case of lesions primarily involving the cells than in lesions of the nerve-roots or nerves. A nerve-root lesion is also generally more serious than a nerve lesion exhibiting an equal degree

of RD, on account of its greater tendency to produce secondary lesions in the cells.

The significance of RD in prognosis is therefore always relative, and entirely dependent on the *nature*, *form*, and *etiological conditions* of the affection in which it is observed.

Only for any one given morbid process, and "all other things being equal," to use Erb's appropriate phrase, can the degree of RD serve as a means of comparison, as an indication of the gravity of the lesions, or for the purpose of distinguishing between slight and severe forms.

In poliomyelitis the degree of RD in each muscle reflects the intensity of the corresponding disturbance in the cord, and indicates the chances of functional recovery in each of them. In a peripheral paralysis caused by neuritis of known nature, the degree of RD will indicate the gravity of the condition and its probable duration. There could be no better example in this connection than that of peripheral facial paralysis *a frigore*, in which *there is no clinical sign affording evidence as to the gravity of the condition*, and the degree of RD is the only source of information which we possess.

It is unwise in any other condition to draw definite conclusions as to prognosis from electrical data, (1) *before allowing RD time to develop* (*i.e.* before the end of the second week in acute cases, such, for instance, as traumatic nerve lesions), (2) *before having followed the evolution of RD by repeated examinations*, either

in order to decide whether it is proceeding steadily towards the stage of absolute inexcitability, or is tending to remain stationary, or in order to establish the fact that a partial RD, which should be a favourable sign, is not actually developing into complete RD, which would indicate that the causative affection is still an active process.[1]

VIII. The Theory of the Elementary Reactions in the Reaction of Degeneration

It is now generally agreed that the paradoxical combination of *faradic inexcitability* and galvanic excitability in a muscle is connected with the factor of duration of the exciting wave. Currents consisting of short waves, such as the faradic current, lose the power of exciting muscles showing the reaction of degeneration, whereas the galvanic current, with its longer wave, does not. With means of diminishing the duration of the galvanic wave, and with discharges from condensers, the duration of which is a function of their capacity, these facts may readily be verified.

This inability of the muscle to respond to short waves indicates morphological or functional changes which it is the business of electro-physiology to explain.

One of the most attractive theories hitherto forthcoming was formulated by Mlle. Joteyko. It is founded on the double function of the muscle as related to its structure. Muscles with abundant sarcoplasm (smooth muscles) would be only slightly excitable by short waves, and their contraction would be slow. On the other hand, muscles rich in differentiated (fibrillary) substance would respond to the faradic current with a brisk contraction. In patho-

[1] The reader will not be surprised at not finding descriptions in this work of certain electrical syndromes, such as the myotonic reaction of Thomsen's disease, the distinguishing reactions in myopathies, and the symptomatic myasthenic reaction of Erb-Goldflam's disease.

These affections are relatively rare in time of peace, and will obviously only occur very exceptionally, if at all, in the neurology of war.

logical conditions giving rise to RD, there would be in some sense a return to the embryonic condition by disappearance of the differentiated substance, and the reactions observed, analogous to those of smooth muscle, would be those of the sarcoplasm.

Galvanotonic and sustained contractions would similarly be modes of response of the sarcoplasm.

The production of a slow contraction apart from degeneration, notably by the action of cold, is not incompatible with this theory if we admit that the sarcoplasm retains its excitability at low temperatures, whereas the differentiated substance only reacts within certain limits of temperature.

An objection to this theory, which Mlle. Joteyko fully recognises as valid, lies in the fact that the excitability of the sarcoplasm is assumed, although no experimental proof of its excitability exists. It is difficult, however, to deny the sarcoplasm a property common to all undifferentiated protoplasm.

Another interpretation is founded on histochemical changes in the muscle.

Cluzet succeeded in obtaining experimental reaction of degeneration in a number of ways—by injections of strophanthin and curare, in muscular fatigue, and in experimental anæmia of the cord. Other physiologists have produced a slowing of the contraction in the frog by injecting various substances—caffeine, veratrine, quinine, etc. Similarly, Reiss obtained analogous results by using solutions of potassium and ammonium, and attributes the slowness of contraction observed in diseases associated with cachexia (diabetes and cancer) to a change of toxic origin in the muscle fibre.

A third opinion involves Schiff's conception of the double origin of the muscular contraction. The latter may be produced either by stimulation of the nerve fibres and nerve endings, in which case the response will be a brisk contraction (Schiff's neuro-muscular contraction), or by direct stimulation of the muscle-fibre itself (Schiff's idio-muscular contraction). In the second case the contraction will be slow.

Strümpell, Babinski, and other neurologists have come to regard the question in this light, and regard the phenomena of the reaction of degeneration, and particularly the slow contraction, as the normal response of a muscle separated from its motor nerve. "The reaction of degeneration," writes Babinski, "is, at least in part, nothing more than the reaction proper to the muscle fibre." [1]

[1] Babinski, *Trav. scient.*, Paris, 1912.

This theory, however, complicates the explanation of partial reaction of degeneration, since notwithstanding the preservation of neuro-muscular excitability to the faradic current, the muscle responds by a slow contraction to the galvanic.

Lapicque [1] returns to the conception of a loss of differentiation in the muscle, following a nerve lesion, and consequent anatomical and functional similarity to smooth muscle. This physiologist discards the sarcoplasm hypothesis, and confines himself to a consideration of the slowing of the contraction, which necessarily corresponds to a diminution of the quickness of excitability. Faradic inexcitability is explained by the fact that the faradic wave is now too short for the slowed excitability, whereas the galvanic current exercises its effect throughout the duration of the excitable phase, just as in the normal state.

The inexcitability of the nerve is due to the fact that its rapidity of excitability remains unaltered, whereas that of the muscle is reduced. Now in the normal state the rapidity of excitability in nerve and muscle are equal: their *chronaxie* (see p. 111) is the same. This isochronism is the condition of transmission of the stimulus from the nerve to the muscle, and this transmission is impossible, if, as in a pathological condition, the rapidity of excitability of the muscle is reduced.

Polar inversion has also been differently explained. Wiener observes that, in a muscle undergoing degeneration, excitability gradually diminishes at the motor point, and its maximum is thus apparently shifted towards the extremities of the muscle. Under these conditions a stimulus applied at the motor point would be ineffective, and the muscle would respond to the virtual pole of opposite sign which excites it at its periphery. In support of this theory, Wiener showed that inversion can readily be produced in the gastrocnemius of the frog by alterations in the muscular tissue brought about by certain solutions. The physiological law of contractions is therefore perfectly compatible with RD, and inversion is merely an apparent modification connected with topographical changes in excitability. Wiener's hypothesis has the advantage of explaining at the same time both the displacement of the motor point and the habitual preservation of the normal formula in longitudinal excitation.

It is difficult, however, to understand why certain cases of partial RD, in which preservation of the excitability of the motor nerve indicates a relatively moderate degree of degeneration, should be accompanied by inversion, and conversely why cases of complete

[1] Lapicque, *Communication orale.*

RD, exhibiting advanced muscular degeneration, should present the normal formula. These are contradictory facts which the theory leaves unexplained.

The sarcoplasm theory is an explanation of polar inversion. Smooth muscle would normally exhibit inversion of the formula. Pflüger's law would be reversed in the case of muscles rich in sarcoplasm. The closing stimulus for undifferentiated protoplasm would be produced at the anode (Mlle. Joteyko). Degenerated muscle, coming to resemble smooth muscle in structure, would consequently obey the same law.

This theory, however, is also open to a definite objection. How, in fact, can it be explained that polar inversion, if it is to be considered characteristic of a muscle undergoing degeneration, is not more constant, and in longitudinal excitation rarely if ever present ?

It will be seen that the question is extremely complex, and that all the suggested explanations have their weak points.

Is the question, after all, one of chemical change in the muscle ?

In animals, particularly in the frog, the normal formula may be varied by impregnating the muscles with solutions of potassium or ammonium. On the other hand, solutions of sodium and lithium cause reversion to the normal formula. It has therefore been debated whether a modification in composition of the cell protoplasm, such as occurs in the reaction of degeneration, would not have the effect of rendering the action of the positive pole more powerful than that of the negative. According to Reiss, the results obtained experimentally by Wiener can best be explained in this way, since in impregnating the muscle with substances affecting the excitability of the motor point, he cannot have prevented their diffusion, and assuming the absorption of toxic substances by the muscle fibre, his theory is virtually equivalent to the theory of chemical change.

IX. The Adoption of a Uniform Technique

Following this study of abnormal electrical reactions, we propose discussing the question of the ambiguity of terms used in electro-diagnosis. What, for instance, is understood by *great faradic, or galvanic, hypo-excitability,* expressions which are currently employed in reports for medical boards ? Beyond what limit

in the strength of current used does galvanic hypo-excitability become "great"? When faradic in-excitability is deduced, was the coil employed one of fine or coarse winding, and were the results obtained by the unipolar or bipolar method, with single shocks or the tetanising current? And was there actually inexcitability to all these forms of stimulus?

It certainly seems that, were an understanding arrived at between electrologists, a greater degree of precision would be a simple matter; the terminology of electro-diagnosis would become a uniform language, capable of expressing reactions and their development in more exact terms, and obviating futile scientific discussions as to the value of different reactions described under the same name.

With a view to such an understanding, we suggest the following standards:

(*a*) *Testing with the Faradic Current.*—It should be understood that all faradic tests are carried out with a standard type of coil and a current of 4 *volts* in the primary circuit, with a secondary coil *of fine wire*, employing the *tetanising* current, by the *bipolar* method. We need hardly emphasise the importance of a uniform voltage in the primary circuit for comparing degrees of excitability. A coil wound with fine wire is employed because strong currents are sometimes required in testing nerves and muscles in a state of hypo-excitability.

With standard apparatus, the measurement of variations in excitability in terms of the distance

between the two coils, although illogical, would be a satisfactory system.

As has already been mentioned, it sometimes happens that a nerve or muscle, which has become inexcitable by the tetanising current, may yet react more or less to single shocks. It would therefore be well to agree not to deduce faradic inexcitability unless the nerve or muscle has been tested by both of these methods, with a negative result in each case. The expression *integral inexcitability* might well be adopted in future to indicate that under the technical conditions described above, excitability is abolished both for tetanising current and single shocks.

(*b*) *Testing with the Galvanic Current.*—1. It should be understood that when inversion is described and no details are specified, inversion *at the threshold* is referred to : strong currents should be mentioned, if inversion is produced by them and not otherwise.

2. Although the character of the contraction is a matter of personal observation, we consider that three degrees should be distinguished : *just perceptible slowing*, *slow contraction*, and *very slow contraction*. The last expression should refer to cases in which the slowing resembles the sluggish reactions observed in lead paralysis.

3. Describing a slow contraction as *unipolar* should be understood to mean that the slowing is only observed at anodal closing, a common circumstance in early stages or mild forms of RD, as has already

been mentioned. The absence of this term should signify that the contraction is slow at both poles.

4. The meaning of the terms *relative longitudinal hyper-excitability* and *absolute longitudinal hyper-excitability* should be defined as already stated (see p. 65). To describe the combination of *abolition of the excitability at the motor point* and *preservation of longitudinal excitability*, we suggest reviving a term which has fallen partially into disuse, *viz.* the *remote reaction of degeneration*, or DRd.

5. By the term *inexcitability* it should be understood that the muscle is no longer excitable by currents which can be tolerated, either at the motor point or by longitudinal excitation.

If excitability be recovered when the indifferent electrode is brought near to the active electrode, the words "*except with the bipolar method*" might be added.

"*Inexcitability, including bipolar*," would infer the absence of response to any current that could be tolerated.

X. Electro-Diagnosis with Condensers

In the course of several preceding chapters we referred to the imperfections of the faradic apparatus, particularly the use of varying and un-standardised instruments, instanced by the archaic but still existing method of measuring intensity in units of distance.

Galvanic technique is also open to a good deal of criticism. Thus, when we read on the milliampere-

meter what we call the liminal intensity, which we have adopted as a measure of excitability, we are merely recording an apparent intensity: in the first place, the skin masks very slight muscular contractions, and we are therefore not measuring the actual threshold; further, since the current diffuses from its point of entry into the body, the zone of the motor point is only affected by a fraction of the total intensity; the action of the neighbouring tissues in regard to this fraction, in itself effective, is that of a shunt. Further, the intensity recorded by the milliamperemeter depends on various factors—the resistance of the circuit, and polarisation in the tissues. Lastly, as was observed by Doumer, when the circuit of stimulation is made, the fall in resistance produced by the passage of the current, only the maximum of which is indicated by the milliamperemeter, prevents our observing the exact moment, and consequently the actual intensity, of the effective stimulus.

Without going as far as to urge, with Doumer, that time spent in this way is absolutely wasted, we cannot but agree that the present method, the farado-galvanic, is far from being exact, and that by it we can only expect to obtain rough measurements, which in practice are only of value when marked changes have already taken place.

To ensure greater accuracy, a number of electrologists have attempted substituting the use of condensers for the classical method.

The condenser, which had already been used

extensively in physiology (Chauveau), was first employed in a systematic way for purposes of electro-diagnosis by Czybulski and Zanietowski.

1. **Condenser Method with Variable Charge.**—We have seen that the duration of the discharge from a condenser is proportional to its capacity. Consequently, if two condensers of different capacity be employed, one giving a short wave of discharge and the other a long wave, the system is analogous to the farado-galvanic, the short wave corresponding to the faradic wave and the long wave to the continuous current wave.

In practice, in the method "*of charging to variable potential*," four condensers, of 0·01, 0·1, 1, and 10 microfarads are used, and for each capacity the voltage is increased until the liminal voltage is obtained. Thus, for instance, tests for excitability are first carried out with 0·01 microfarad. If the maximum available voltage (80 to 110 volts) gives a contraction with this low capacity, the capacity of 10 microfarads can at once be used for obtaining stimuli with long waves. In cases in which the muscle does not respond to 0·01 microfarad, 0·1 microfarad is tried. When the liminal voltage has been recorded, further tests are carried out as before, with 10 microfarads. If 0·1 microfarad, corresponding to short waves, is without effect with the maximum voltage, 1 microfarad is used, and so on.

Apart from the fact that the testing apparatus is constant, the principal advantage of condensers is that they permit a more accurate estimation of variations in excitability with short waves. The delicacy of the method enables the neurologist to follow variations in voltage, and consequently changes in the electrical reactions, more closely than the farado-galvanic method permits.

In spite, however, of its undeniable advantages, this method is open to objection, in that it is somewhat laborious. It is generally regarded as too complex, and comparatively few have become adepts with it.

2. **Method of the Condenser of Variable Capacity.**—The factor of the *duration* of the stimulus, the import-

ance of which will be seen in the next paragraph, suggested to Cluzet an entirely different method from that of fixed capacities, founded on the employment of *a condenser the capacity of which could be regulated.*

Described by the author for the first time in 1911,[1] this method is in use at the electro-radiological centre at Lyon, and in several secondary centres in the 14th Region.

Its principle consists in determining the lowest capacity, that is to say the shortest wave, giving the threshold of muscular contraction.

As in ordinary electro-diagnosis, the method concerns itself with the form of the contraction, the relative action of the two poles, and the longitudinal reaction.

As it is possible to utilise a long series of waves intermediate between the short wave given by the lowest capacity (equivalent to the faradic wave) and the long discharge (analogous to the galvanic current), a whole series of degrees of RD can be distinguished in muscles exhibiting the reaction, which could scarcely be differentiated by the farado-galvanic method.

In certain cases of very marked RD, the largest condenser, the duration of the discharge of which is too short, produces no effect. Under such conditions, instead of employing a greater capacity, which would render the apparatus bulky and cumbersome, an additional resistance is introduced into the circuit,

[1] Cluzet, "Méthode et appareils nouveaux pour l'électro-diagnostic," *Lyon Méd.*, Nov. 26th, 1914.

the effect of which is to lengthen the duration of the discharges without affecting the actual quantity of electricity.

The following is a brief summary, adapted from Cluzet, of the technique of the method employing the condensers of variable capacity.

In the first place, the value of the normal liminal capacity with the voltage used, is determined by means of the apparatus described on page 14. With 110 volts, normal nerves and muscles usually respond to approximately 0·02 microfarad, the indifferent electrode being 100 sq. cm. in area, and the active electrode 1 sq. cm.

Hyper-excitability and hypo-excitability are then indicated by the relation between the capacity giving the threshold and the capacity of 0·02 microfarad.

In the case of hypo-excitability the slowness of the contraction will indicate the reaction of degeneration.[1] If the muscles exhibiting this hypo-excitability, together with slow contraction, are still excitable indirectly through the motor nerve, partial RD will be deduced. If they are not, it is a case of complete RD.

When no response can be obtained with any of the capacities, additional resistances are successively introduced into the circuit. Only after this final test can the absence of contraction be held to indicate inexcitability of the muscle.

[1] It should be observed that the condenser never gives the galvanotonic reaction.

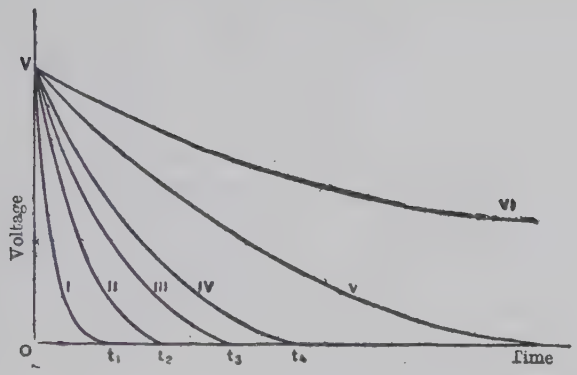


FIG. 38.—I, II, III, IV, etc., are curves representing the discharges of condensers of increasing capacity charged to the same potential (V). The time intervals Ot_1, Ot_2, Ot_3, are proportional to the capacities of the condensers which have given the curves I II, III, etc.

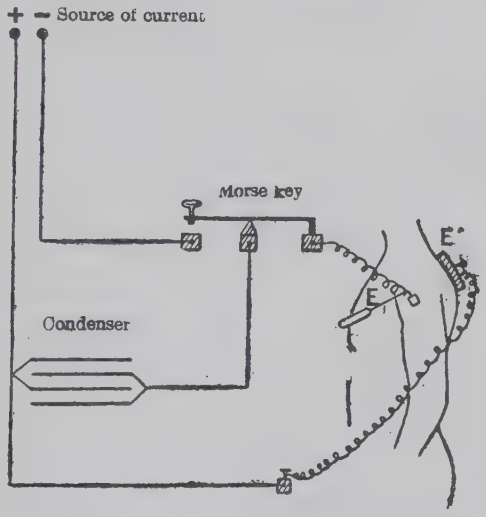


FIG. 39.—Condenser method. The condenser is connected to the source of supply when the Morse key is depressed. It is discharged through the patient when the key resumes its position of rest. At E, the active electrode; at E′, the indifferent electrode.

XI. TRUE EXCITABILITY—ITS MEASURE, THE CHRONAXIE

The Law of Excitation and the Chronaxie.—The criticisms brought against the current method in electro-diagnosis to which we have referred above are of small importance by comparison with a fundamental objection of a different nature. The electrical diagnosis of the present day is based on the assumption *that the property of tissues known as excitability may be measured in terms of intensity.*

Now although it is true that in practice the measurement of excitability in terms of liminal intensities, a method which has been general since the days of Duchenne and Erb, is daily of the greatest clinical value, is not this system of measurement purely conventional ? Is excitability really and exclusively a function of the intensity ?

Is it not also peculiar that measurements of two forms of excitability, faradic and galvanic, should have to be carried out, where only a single means of stimulation is concerned ?

As far as the theory of excitability is concerned, the problem has to a great extent been solved by the work of certain present-day physiologists.[1] The difficulties of measurement in practice, however, have not yet been overcome.

The absence of response to the faradic current, *i.e.* to short waves, in certain pathological conditions of

[1] See in particular : Lapicque, *Soc. de biologie*, 1909, and *Revue générale des Sciences*, Feb. 1911, and Laugier, *Thèse de Paris*, 1912.

the nerves, might have been expected to call more attention to the importance of the factor *duration* in the phenomena of stimulation.

Engelmann [1] was the first of the physiologists to comprehend the influence of the time occupied by the passage of the current on the phenomena of stimulation, and to regard the *physiological time* as a property of the tissue.

It was not until much more recently (1891) that Hoorweg stated the law establishing the relation between the two factors, *duration* and *intensity*. He observed further, with the condensers which he was using, that with a certain kind of discharge, that is to say with a stimulus of a certain duration, the energy reached a minimum. The corresponding duration was subsequently considered by Waller as a characteristic of the tissue stimulated.

The study of the law of excitation and the effect of the duration of the passage of the current was again undertaken by Weiss. Instead of employing waves of discharge from condensers (Hoorweg), Weiss worked with rectangular waves obtained by the very rapid make and break of a continuous current. He deduced the following law from the results of his experiments.

An electrical stimulus is effective only when a constant quantity of electricity is employed, increased by a variable quantity proportional to the duration of the discharge.

[1] Engelmann, "Beitr. z. allg. Muskel. u. Nervenphysiol.," *Pflüger's Arch.*, t. III and IV.

This law is expressed by the following formula :

$$Q = a + bt$$

where Q represents the quantity of electricity employed, t the duration of the current, and a and b two coefficients peculiar to the tissue concerned.

The exact significance of these two coefficients was at first not understood. Zanietowski regarded the coefficient a as representing the initial quantity of electricity required to charge the capacity represented by the tissues, and the factor b as the intensity (varying with the resistance of the tissues and electrodes) of the continuous current passing through the body. It at once became evident that a and b underwent the same variations in all the experiments carried out, and consequently that their relation remained practically constant.

Since, in Weiss's formula, the coefficient a is a *quantity*, and the coefficient b an *intensity* (since bt, product of an intensity and a time, is a quantity), the quotient $\frac{a}{b}$, the quotient of a quantity by an intensity, must of necessity be a time. This time $\tau = \frac{a}{b}$ is therefore, in the same way as a and b, a characteristic of the tissue : it is a *time constant*, independent of experimental conditions.

It is high in the case of muscles of which the contraction is slow, low in those which contract rapidly, varying inversely with their *rapidity of excitability*,

and corresponding exactly to Engelmann's "physiological time." This is the *chronaxie* of Lapicque.

Briefly, whereas the measurement of excitability by the ordinary determinations of intensity is purely arbitrary and without physiological basis, that of the relation $\frac{a}{b}$ gives a constant, proper to the organ concerned and independent of any other factor.

Measurement of the Chronaxie.—The measurement of the chronaxie has been carried out in physiology by several means. The simplest procedure (Lapicque) consists in determining the duration of the stimulus required with an intensity twice that which will give the threshold contraction when a current of prolonged duration is used.[1] Hitherto, however, it has not been possible to apply any of the procedures employed in physiology, to man.

The importance, however, from the clinical point of view, of possessing a simple method by which the rapidity of excitability of affected nerves and muscles could readily and rapidly be determined, will at once be understood.

What has been called the "*effective time*" can be estimated to some extent by Cluzet's method of condensers of variable capacity, already described. The results obtained vary as the chronaxie, and the method may therefore be regarded, if not as a definite measurement, at least as affording an indication.

[1] This intensity of a current of indefinite duration giving the threshold was designated by Lapicque the "rheobase."

In the same way the procedure of obtaining the *indices of rapidity* (Bourguignon and Laugier) cannot be said to give a measure of the chronaxie, but affords corresponding indications.

The principle of the Bourguignon-Laugier method is to determine the relation between the quantities of electricity required for a liminal make and a liminal break stimulus, in the case of a given nerve or muscle, the same apparatus being used in each case. It has been shown, by the work of Mmes. Lapicque and J. Weill, that the relation between the quantities corresponding to the two waves, classes nerves and muscles in the same order as their rapidity of excitability.

In applying the method, a coil is used which will readily give both thresholds; and the intensity (in cms.) of each of the two waves which gives the threshold is determined by successive increases in the closing current.

The opening contraction is eliminated by a special interrupter while the closing contraction is being tested for, the opening stimulus being extremely painful to the patient in cases where the threshold for closing stimuli is considerably raised.

If the equivalents, in quantities of electricity, of values in centimetres of approximation, have already been determined (by means of a ballistic galvanometer), reference to these will give the quantitative relation desired.

This relation is constant for any given muscle;

for the majority of normal muscles it is in the neighbourhood of 15. In pathological conditions it falls more or less below this figure.

The only disadvantage of the method is that it can only be applied to cases in which faradic excitability has not been lost. In other words, it cannot be used in complete RD. It is true, on the other hand, that it can be used to follow the early evolution of RD very closely, and that it is applicable to all cases of partial RD.

The *direct measurement* of the chronaxie was attempted by Cluzet with the condenser, and effected by Lapicque by means of his chronaximeter.

Cluzet's procedure consists in determining which of several capacities giving the threshold will give it with a minimum of energy.

A potential-reducer for varying the charge and a voltmeter to record the potential of the charge are placed in the circuit.

The threshold voltage is determined for a number of capacities. The energy expended in each of these cases is calculated ($E = CV^2$), and the lowest figure gives the *optimum capacity* C.

The measure of the characteristic of excitability is then obtained by the formula :

$$\text{Characteristic} = RC$$

which, as will be seen, necessitates measurement of the resistance.

Lapicque's *clinical chronaximeter* is a rotatory

rheotome recording directly the passage of currents in terms of absolute time, which may be regulated at will from a thousandth to a tenth of a second.

The apparatus consists of a motor system and an interrupter system.

The motor system is actuated by the fall of a

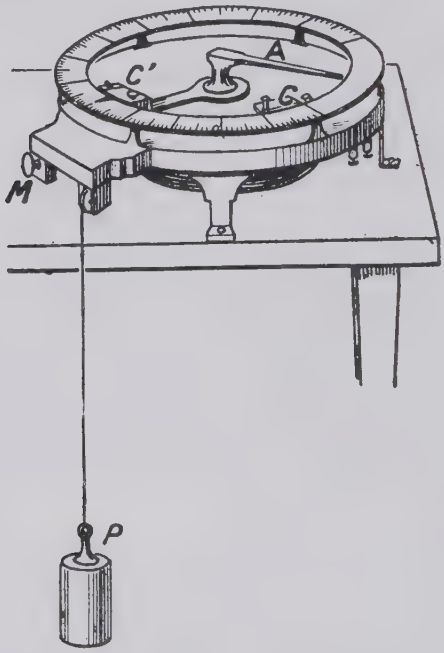


FIG. 40.—Lapicque's chronaximeter.

weight P. The cord by which this is suspended is wound on a spiral conical pulley, the axle of which therefore revolves with an acceleration which equals the square of the time. A needle A, mounted perpendicularly on this axle, describes an arc which records the graduation of the apparatus in fractions of a second.

By engaging the levers C and C^1, this needle successively makes and breaks the ordinary galvanic circuit of an electro-diagnosis table, in which the apparatus is placed. By increasing or decreasing the distance between the two mechanisms of make and break, the lapse of time between the two waves, or, in other words, the duration of the current, can be varied at will.

To use the chronaximeter, the galvanic threshold is first tested for with Courtade's key; the apparatus is wound up, and then released. Should no contraction occur, the duration is too short. By gradual further separation of the contacts, a point is reached at which a contraction is produced. The contacts are then approximated until no further contraction occurs.

This minimum distance between the contacts is then read off on the circumferential scale of the apparatus.

This figure, however, does not correspond to the chronaxie itself, since the apparatus measures, not the chronaxie, but the "effective time."

The effective time is the minimum time for which the key of an interrupter must be kept down, in order to obtain the threshold. It is a multiple of the chronaxie, roughly equal to ten times the value of the latter.

The effective time for the human muscle is about 0·002 to 0·003 seconds (chronaxie: $0^{\sigma},2$ to $0^{\sigma},3$), which corresponds to close approximation of the two contacts.

In the pathological state the distance between them is increased.

After a nerve lesion, a muscle exhibiting signs of definite degeneration by ordinary methods gives an effective time of one-tenth of a second (chronaxie : 10σ) or even longer, *i.e.* fifty times greater than the normal.

In cases of partial RD, intermediate figures are given, indicating chronaxie of 1 or 2σ to 10σ, according to the degree of degeneration.

The chronaximeter fills an important place in electro-diagnosis. The simplicity of its construction and the ease with which it can be manipulated are a guarantee for its future. Introduced in 1915 by Lapicque, its use is being studied in many laboratories.

CHAPTER III

ELECTRO-DIAGNOSIS IN MOTOR PARALYSES

I. Traumatic Paralyses of Nerves

The motor paralyses due to changes in the peripheral nerves which occur in the pathology of war are due, either to traumatic or to toxic and infective causes.

The latter, with which may be included the paralyses of hitherto undiscovered cause referred to as rheumatic, or *a frigore*, are of a purely medical character, demanding medical and physiotherapeutic treatment, and do not involve the complex problems of traumatic paralyses. The electrical reactions to which they give rise will be studied in a later chapter.

In the category of traumatic paralyses we shall introduce in the first place paralyses from section, contusion, and stretching;[1] and secondly, paralyses from continuous and prolonged compression, whether of exogenous origin (aneurysm, hematoma, abscesses, splinters of bone, callus, involvement in scar tissue, fibrous bands, etc.), or of endogenous origin, as in traumatic neuroma.

[1] Further causes in this category are burns, irritating injections of ether, alcohol, cocaine, and camphorated oil, either into the nerve or in its immediate neighbourhood.

This etiological classification, though necessarily incomplete, is clear and convenient, but does not always correspond with clinical experience.

Gunshot wounds are often complicated, and the cause of the nerve changes is not certain. In open wounds, for instance, whether suppurating or clean, and in compression by purulent accumulations, we cannot determine the extent of the part played by infective neuritis, which is sometimes latent, in the process causing paralysis. Similarly, surgical intervention has shown that partial division, neuroma, and involvement in a mass of scar tissue, are often present together in the case of the same nerve.

It will therefore be understood that each of these conditions may exercise varying degrees of effect on the electrical reactions.

Differential Diagnosis.—Differentiation between the traumatic nerve lesions mentioned above, division, contusion, and compressions of all kinds, and pathological conditions of a hysterical, reflex, or imaginary nature, offers no difficulties when marked changes in the electrical reactions have occurred. The discovery of profound alterations in electrical excitability, and, *a fortiori*, of the existence of RD, affords definite information, the value of which calls for no further discussion.

There is only room for doubt when the electrical reactions are only slightly modified: it should be remembered that *the absence of abnormal reactions is not absolute proof that the nerve is unaffected.* Huet [1] has described slight irritative forms, the organic nature of which is established by the distribution of the muscular atrophy, the presence of definite painful points, and sometimes even by an absent or feeble

[1] Huet, "Les troubles de l'excitabilité électrique des nerfs et des muscles" *in* M. et Mme. Déjerine et Mouzon, *Presse médicale*, August 30th, 1915.

tendon reflex in a case where electrical examination reveals no appreciable alteration in excitability of either nerves or muscles.

Electrical testing may seem superfluous in many cases, since clinical methods, embracing a number of cardinal signs and a large variety of slighter indications which recent work has afforded the neurologist, generally suffice to differentiate between organic and functional paralyses.

In spite of this, the electrical method should invariably be applied, in the first place because it verifies previous conclusions, an additional safeguard against ever-present possibilities of error; further, because it may undeniably lead, in some cases, to reconsideration of a hasty or even apparently well-founded diagnosis; and finally because, where organic lesions and functional disturbance coexist, it is almost the only means we have of defining the extent of each of these.

Similarly, when several nerves are affected at the same time, the electrical reactions indicate in what degree each is involved.

Evidence afforded by Electro-Diagnosis as to the Nature of the Lesion.—In the case of a wound, when the possibility of a non-organic cause has been eliminated, the principal question is that of the nature of the lesion (division, compression, or irritation), since it is upon this that the form of treatment depends (physiotherapeutic, surgical, or expectant).

The most serious possibility in a motor paralysis is complete division of the nerve, a condition which calls for surgical intervention and suture.

Now numerous observations extending over the last few years have not educed any infallible clinical sign of nerve division. Similarly, the syndromes of interruption and compression, solidly founded as they are, admit of such considerable error that conclusions drawn from them can only be provisional.

The numerous smaller signs recently described, such as vaso-motor disorders, absence of sweat reactions, hypotrichosis, and cicatricial topo-paræsthesia, are considered valuable indications of a serious nerve lesion, but afford no evidence as to its nature.

The evidence obtained by electrical methods is similarly indefinite, but taken in conjunction with the clinical signs it is of such importance that no observation omitting reference to the electrical reactions can be regarded as complete.

Evidence of division of the nerve in man is afforded by the complete reaction of degeneration. Its characteristics require no further description, as this particular lesion was taken as the type in the study of complete RD and its evolution.

Every case of nerve section is therefore characterised by complete RD. The converse, however, is not true; the existence of RD does not necessarily imply that the anatomical continuity of the nerve is broken, or that the lesion is incapable of repair. Com-

pression and neuritis may also give rise to complete RD.

Under these conditions, what is there in the intrinsic characters of the reaction of degeneration to indicate the nature of the causative lesion ?

Significance of the Rapid Evolution of RD.—A fact of which sufficient account is not taken in electro-diagnosis is expressed in the following proposition : RD is always in continuous evolution, and the syndrome of that name is merely a *transitory manifestation.*

The elementary reactions which, taken together, are said to constitute the reaction of degeneration, characterise the complete reaction, that is to say RD in its typical phase.

Now this typical phase is preceded by an initial period, and followed by a terminal period. Obviously the evolution of the causative lesion will control the evolution of RD, and much can consequently be gained from an analysis of the latter.

A single electrical examination, revealing partial or complete RD, can never give an adequate idea of the process at work. If the full possibilities of electro-diagnosis are to be utilised, and a conclusion as to the nature of the paralysis is to be founded on as complete a series of indications as possible, it is essential to follow the early stages in the evolution of RD as closely and exactly as possible.

RD is, in fact, best compared to the temperature in pyrexia. The nature of a fever is not suggested by

simply taking the temperature once; obviously, to any intelligence, its diagnostic value lies in its variations, and therefore in the whole chart.

The practical corollary of this comparison is that it is absolutely necessary, in cases of peripheral nerve lesions, to undertake repeated electrical examinations; in fact, to carry out a series of examinations at regular intervals. The most interesting and important phenomena are possibly those developing early, during the first two weeks following the injury. At this period an initial examination is particularly instructive. It is therefore important that any patient suffering from a motor paralysis should immediately be sent where a weekly examination by an experienced electrologist could be combined with the treatment of his wound. The presence of a wound is no obstacle to such an examination, since it could be carried out under perfectly aseptic conditions.

To determine whether different electrical phenomena follow division and compression of a nerve, it was natural to resort to experimental methods. We accordingly resected 2 cms. of the right sciatic in a dog, and compressed the left sciatic with a non-absorbable ligature. In spite of the serious nature of these lesions, the animal remained paralysed only for a few days. At the end of the first week it appeared entirely to have recovered the use of the two paws.[1]

The electrical reactions were tested every week for about five weeks; on two occasions the nerve and muscle were exposed and stimuli applied directly. The following were the principal observations:

On the right side (nerve divided), the peripheral end of the

[1] This paradoxical phenomenon is well known to physiologists, and indicates a peculiar power of rapid replacement and adaptation in the dog.

sciatic was no longer excitable. Stimulated at the motor point, the internal portion of the gastrocnemius (which was selected for testing) showed towards the tenth day a marked galvanotonic contraction, without inversion of the formula. Stimulated in the region of the tendon, hyper-excitability appeared rapidly, with slow contraction and inversion. Later, excitability diminished at the motor point. The galvanotonic contraction persisted, but was only given by stronger currents. Inversion of the formula occurred. The manifestations of longitudinal excitability persisted in the form of a slow contraction with inversion.

On the left side (compression), the nerve could still be excited above the lesion. The contraction was at first only tonic at anodal closing; later, both poles gave a galvanotonic contraction. Hyper-excitability was shown particularly by the great ease with which the KC contraction was obtained. Inversion was not observed at any period. In longitudinal excitation, the KC contraction appeared slow and the AC tonic: there was no inversion, but a nearer approach to equality of the KC and AC thresholds than normally.

Briefly, compression was followed by a slower evolution, a more marked stage of hyper-excitability, and the absence of inversion.

It goes without saying that the reactions observed in this experiment would not necessarily be reproduced in similar experiments. They would chiefly depend on the nature and degree of the compression, developing differently in cases of slight compression, whereas in rapid and severe compressions they would be practically equivalent to experimental section, and give rise to an electrical syndrome identical with that produced by division of the nerve.

In the case of wounds, immediate section, that is to say by a projectile in action, is followed by a *rapid evolution* of the electrical reactions.

The initial phase of RD (characterised by progressive diminution of faradic and galvanic excitability in the nerve, progressive diminution of faradic excitability, galvanic hyper-excitability, and then hypo-excitability, in the muscle, and a tendency to slower contraction), assumes an acute aspect, and extends over two or three weeks. At the end of this time

the typical phase of the complete reaction of degeneration appears; the nerve has become inexcitable, and the muscle does not respond to the faradic current, but the galvanic causes a contraction which is either slow or tonic.

This acute evolution, taken in connection with the theory of its causation, observation of the track of the projectile, the manner of onset of the paralysis (complete immediate paralysis), and the initial pain (fulgurant pain), suggests a strong probability that the nerve has been severed.

It is nothing more, however, than a *probability*, for the same acute syndrome may follow simple violent contusion of the nerve, or severe compression by a splinter of bone or hæmatoma.

More commonly the case is not examined until several weeks or months afterwards, and if, at this time, the patient no longer remembers the early circumstances connected with his wound, the problem is a much more difficult one. There is nothing to indicate whether the paralysis follows from division of the nerve, severe and sudden compression, slow compression, or neuritis. It is impossible to reconstitute the evolution of the electrical reactions. We are faced with RD in its typical phase, and none of its characters indicates its mode of development, whether acute or slowly progressive.

In animals, after section of a nerve, the progressive evolution of RD terminates ultimately, after several months, in absolute inexcitability. The muscle ceases

to respond to longitudinal stimulation and so on, even with the strongest currents.

In man, absolute inexcitability, observed some weeks after the injury, is an extremely serious sign, indicating severe lesions of the nerve and muscle, but not necessarily implying severance of the nerve.

On the other hand, persistence of excitability in the muscle (longitudinal excitation) for several months, does not always mean that the nerve has not been severed. In man, the typical phase of RD is continued for much longer than in the animal, and the stage of inexcitability may not be reached for many months.

The Reaction of Conductivity.—The physiologist Schiff, in experimenting on nerve compression, observed that nerves which were no longer excitable by electric stimuli applied below the point of compression, continued nevertheless to respond to stimuli above that point.

This physiological phenomenon of the individual character of the two nerve functions, excitability and conductivity, is seen again, as we have noted, under different conditions—those of electro-diagnosis. Erb in particular, emphasises it strongly in connection with regeneration of the nerve (see p. 139).

The peculiar condition of continued excitability above the lesion in nerve injuries was recognised by Claude, Vigouroux, and Dumas,[1] who observed it in

[1] Claude, Vigouroux, and Dumas, "Cent cas de lésions traumatiques des nerfs des membres," *Presse Méd.*, March 4th, 1915.

a number of their cases. Battez and Desplats,[1] however, availing themselves of Schiff's discoveries, have been chiefly instrumental in proving the diagnostic value of conductivity, basing their conclusions on numerous observations.

If two faradic electrodes be applied close together immediately above the lesion, in a nerve whose excitability below this point is abolished, stimulation may be ineffective, or, on the other hand, it may provoke contraction in muscles situated distal to the lesion. In the latter case, the nerve, although its excitability is lost, has not lost its conductivity. This persistence of conductivity is *absolute proof that the continuity of the nerve is not broken*, and renders the diagnosis of section inadmissible. Here again, however, the converse is not true ; absence of the conductivity reaction does not necessarily mean that the nerve is severed.

Battez and Desplats observe that the reaction of conductivity may be tested for by bipolar faradic stimulation, and when this is without effect, by *bipolar galvanic stimulation*. This procedure revealed the reaction of conductivity in several cases which gave negative results on faradic stimulation, and in which, therefore, the continuity of the nerve would not otherwise have been proved.

The Reaction of Inversion.—It follows theoretically from the results of experiments that inversion is an

[1] Battez and Desplats, " Excitabilité et conductibilité dans les traumatismes du nerf par blessure de guerre," *Bull. Ac. Méd.*, January 18th, 1916.

integral part of the syndrome following complete nerve section. It appears also to have been observed in all actual cases of complete section, as verified by operation.

According to Bourguignon, when there is no inversion *at the threshold*, the hypothesis of severance should be abandoned.[1]

Inversion is not, of course, a specific reaction in nerve section ; it is observed in other cases (exogenous and endogenous compressions).

The Distribution of the Reactions.—Another sign of complete severance is that the electrical reactions are modified in the same degree throughout the region supplied by the nerve. In cases of partial severance, however, and in certain compressions, the abnormal reactions are distributed unequally among the different muscles ; in the latter case, the faradic reactions of the muscles are usually absent; but whereas certain muscles give a brisk contraction on galvanic stimulation, in others the contraction is slow. Pierre Marie, Gosset, and Meige [2] have shown that the fibres supplying different groups of muscles may be isolated by direct excitation. It will be evident that partial severance, or a neuroma in contact with the nerve, may affect certain muscles to the exclusion of others.

This sign is of particular value in injuries of the

[1] " Les procédés modernes d'électrodiagnostic," *Cong. de l'A. F. A. S.*, Le Havre, 1914.

[2] P. Marie, Gosset, and Meige, " Les localisations motrices dans les nerfs périphériques," *Bull. Ac. de Méd.*, December 28th, 1915.

median and ulnar nerves, which are frequently connected with multiple wounds; its value is less in lesions of the radial and external popliteal (Mme. Benisty [1]).

Differential Signs in Severe Lesions.—It will be understood from the foregoing that there is no definite and specific sign indicating the nature of the nerve lesion. Conclusions can only be drawn from a group of reactions, certain of which are definite evidence that the nerve is not severed, and others strongly suggest that it is.

A. *Reactions indicating continuity of the nerve:*

1. Incomplete RD or modifications of excitability (quantitative only).
2. Absence of one of the secondary signs of complete RD; absence either of longitudinal hyper-excitability or of slowing of the KC contraction at the motor point.
3. The reaction of conductivity.

B. *Reactions suggesting* (but in no case proving) *division of the nerve.*

1. Acute evolution of RD.
2. Absence of the reaction of conductivity.
3. Inversion at the threshold.
4. Distribution of the same degree of RD throughout any given region.
5. Persistence of hyper-excitability only in longitudinal excitation.
6. Rapid development of absolute inexcitability.

[1] Mme. Athanasio Benisty, *Traitement et restauration des lésions des nerfs*, Paris, Masson, 1917.

In reality, apart from cases in which the development of the reactions is acute and immediate, accompanied by a clinical history suggesting that severance has occurred, the reactions enumerated in the second category indicate the existence of a severe lesion of the nerve, functionally equivalent to actual severance.

Neuromas and severe compressions may give these reactions in the same way as division of the nerve, and consequently the question of the nature of the lesion may remain undecided; such a case, where electrical tests reveal a serious state of affairs, requires operative treatment, at least of an exploratory nature.

On the other hand, the reactions in the first category, indicating continuity of the nerve, and more particularly suggesting exogenous or endogenous compression or neuritis, afford a reasonable hope of spontaneous recovery, and indicate appropriate medical treatment. Only in the case of aggravation of the clinical and electrical signs is an operation necessary.

Discrepancies.—In several cases it has been observed with some surprise that the electrical reactions do not appear to correspond with the clinical signs or with the gravity of the lesion revealed by operation.

In two cases, for instance, of sciatic paralysis with marked RD, Basset,[1] after minute examination, could find no visible lesion of the nerve. In regard to the possible objection that this lesion might have escaped him, he avers that the macroscopic appearance gave

[1] Basset, *Rev. de chir.*, April and May 1916.

no suggestion of injury to the nerve at any point; hence he was forced to deduce simple contusion complicated by a profound state of stupor.

Cases of this nature, where in spite of obvious clinical signs and greatly changed electrical reactions, an operation reveals only lesions apparently inadequate to explain these phenomena, are extremely rare in our experience. It seems likely that neuritis, in the inflammatory sense of the word, is a factor which affects the electrical reactions more often than is supposed.

On the other hand, cases have been described where, in spite of extensive or severe compression, giving rise, previous to operation, to serious organic disorders, muscular atrophy, etc., excitability was found to be merely diminished, or even unaltered; in explanation it was suggested that the nerve might acquire a kind of tolerance or power of adaptation to compression.

This absence of changes in the electrical reactions in a case of evident compression with trophic or motor disturbance, should, however, be regarded as an exceptional occurrence. When it does exist, it should be remembered that preservation of the electrical reactions may possibly be accounted for by some anastomosis or abnormal innervation (see p. 151).

There is really, however, no question of tolerance in regard to electrical reactions.

Tolerance or adaptation, in as far as the clinical signs are concerned, may undeniably occur. Ombré-

danne has recently published an undoubtedly authentic case of it.[1] An operation had been necessitated by an entirely different condition, and the radial nerve was found to be involved in a large mass of scar tissue. There had been no functional disturbance to suggest a compression of the nerve.

According to Ombrédanne, cases of this kind, where considerable lesions give rise to no disorder of function, are decidedly rare.

Our experience, however, in carrying out numerous electrical examinations for the purposes of Medical Boards, obliges us to take the opposite view. On many occasions we have discovered changes in the electrical reactions, indicating a more or less severe nerve lesion, in patients with no sign of motor or trophic disorders. Cases in which some anomaly in the muscular reactions, as revealed by electrical methods, indicates a compression not clinically recognised, are still of relatively frequent occurrence.

The Reactions of the Exposed Nerve.—If, before an operation, electrical examination has afforded no definite conclusion, would not electrical testing on the operating-table afford more precise information as to the functional value of the injured nerve ?

This procedure would be unnecessary in a case of " discontinuous " section of a nerve, as Claude has expressed it, where the two cut extremities have become more or less widely separated. It would be

[1] Ombrédanne, *Soc. chirurgie,* March 28th, 1917.

equally unnecessary if a structure easily removed were found to be causing compression, such as a band of scar tissue, or an accumulation of blood, etc. On the other hand, in the case of a neuroma, a nerve keloid, or a fibrous connection, a conclusion must be drawn at once, as the surgeon must decide whether the continuity of the nerve is or is not interrupted, whether it is advisable not to interfere, or whether, on the contrary, he should boldly divide and trim it, and oppose and suture the two extremities.

Electro-diagnosis in an operation wound, formerly practised by Bergonié,[1] was exhaustively studied by Pierre Marie and Meige.[2] The exposed nerve is tested with the faradic current by means of a silver or platinum bipolar electrode (single shocks from a coil of coarse winding). If excitability is preserved, Pierre Marie and Meige advise simply trimming and freeing the nerve from neighbouring adherent or bony structures. If, on the other hand, faradic excitability, both above and below the lesion, is abolished, and at the same time "section or marked flattening with an indurated neuroma occupying the whole thickness of the nerve" is discovered, the small chances of ultimate recovery of function suggest excision of the altered segment and suture of the two ends. A

[1] Bergonié and G. de Fleury, "Paralysie radial grave par contusion légère. Electrodiagnostic sur le nerf mis à nu et sous chloroforme. Pronostic défavorable," *Arch. d'Électr. Méd.*, January 1901.

[2] Pierre Marie and Meige, "Électrisation du nerf mis à nu," *Bull. Acad. Méd.*, February 9th, 1915.

less serious lesion will require only a conservative operation.

The method of P. Marie and Meige, based on the condition of faradic excitability, is therefore to differentiate, in the wound, between partial and complete RD : in the former case, the operation will be merely one of freeing from surrounding structures ; in the latter it will depend upon the macroscopic appearance of the nerve lesion.

Léri [1] applied electrical methods in the wound in 72 cases of nerve injury. Of these 72 cases, in 8 he found total "discontinuous" section, and absence of faradic excitability; in 15 "continuous" section, that is to say, with a bridge of cicatricial substance, adherent to the neighbouring tissues. In all these cases, as might be expected, there was no faradic response.

In 24 cases in which the nerve was macroscopically intact, and merely more or less adherent to neighbouring tissues, the faradic response was given in 23.

The faradic response in neuromas, however, is variable, sometimes positive, sometimes negative.

In 16 cases of nodular neuroma centred in the axis of the nerve, 8 showed faradic conductivity, which is absolute proof of the continuity of the axis-cylinders ; 8 had lost it. Lastly, of 9 cases of lateral neuroma, in 8 there was no response in the region corresponding to the situation of the neuroma.

[1] Léri, "L'Électrisation directe des tissus nerveux au cours des interventions pour blessures des nerfs," *Paris Méd.*, June 26th, 1915.

It follows from these observations that for purposes of deciding at the last moment whether a neuroma is permeable by stimuli, the method offers certain advantages.

Similarly, a further purpose would be to verify the results of preliminary transcutaneous testing, and to indicate the exact condition in cases of doubt as to the preservation of excitability or faradic conductivity in the nerve. Lastly, in some cases where pronounced œdema or adiposity interfere with the usual electrical examination, direct testing of the nerve will complete our knowledge of the reactions.

Tinel, however, criticises the procedure on the ground that it may lead to the resection of a nerve in process of spontaneous regeneration. Faradic excitability is absent in the initial stages of repair, and remains so until the power of voluntary movement returns, and consequently in relying on this factor alone there would be considerable danger of resecting motor fibres in which the process of regeneration was far advanced.[1]

The Return of the Electrical Reactions.—There is no doubt that serious cases of paralysis have been known to improve under persevering medical treatment.[2]

Some authors, in anticipation of spontaneous

[1] Tinel, *Les blessures des nerfs*, Masson, 1916.

[2] Tinel noted improvement in 60 to 70 per cent. of nerve lesions examined 8 to 10 months after the original injury.

recovery,[1] go so far as deliberately to avoid any attempt at treatment.

Of the physiotherapeutic treatment, the galvanic bath, from its circulatory effects, the continuous current, from the sclerolytic effects of the negative pole, the value of which one of the present writers has continually emphasised in the past,[2] the introduction of certain anions (iodide of potassium [3]), which is doubtless merely a variation of the processes of electric sclerolysis, and lastly radiotherapy,[4] have to their credit a large proportion of favourable results which should certainly be taken into consideration.

Hitherto, however, the repair of anatomical nerve lesions has more frequently been attempted by surgical methods.

The freeing, by surgical means, of nerves undergoing compression, enclosed in a mass of scar tissue, involved in a callus, or displaced and stretched by a ridge of bone, is generally followed, after a variable interval, by recovery of function. With sutures, however, it is a different matter, to judge by statistics hitherto published. Before the war, it was customary to suture divided nerves as soon as possible, and the

[1] Huet mentions a case of spontaneous recovery of a radial paralysis following a fracture of the radius. An operation was about to be undertaken when in three days a remarkable improvement occurred.

[2] Zimmern and Cottenot, "La sclérolyse électrique," *Presse Médicale*, June 25th, 1910.

[3] Chiray and Bourguignon, "L'ionisation des cicatrices de guerre," *Presse Méd.*, August 3rd, 1916.

[4] Hesnard, "Le traitement local et la radiothérapie locale des blessures des troncs nerveux," *Arch. d'Élect. Méd.*, January 1916.

operation, being aseptic, was frequently followed by functional recovery a few months later. Gunshot wounds being generally infected, it became necessary to postpone nerve suture, a condition of affairs which was the more unfavourable because the muscles subsequently became the site of more advanced trophic changes.

In spite of this, good results have been obtained in a number of cases, though always after an interval of many months.

It is true that cases of almost immediate motor recovery have been recorded (by Cazamian[1] in France, and by Lœwenstein[2] in Germany, etc.). These results could scarcely have been hoped for, since it is known that after section of a nerve, the peripheral end degenerates throughout its entire length, and direct regeneration is only possible when the axons of the proximal have penetrated the peripheral end.

Nerves possess a definite individuality (Dumas) from the point of view of the rapidity and completeness of their functional restoration. The progress of the regeneration varies even with the height of the lesion, for the reason that the axis-cylinders have a greater or lesser distance to traverse. The radial is

[1] Cazamian, "Sur trois cas de suture nerveuse suivie de rétablissement des fonctions du nerf," *Soc. chirurgie*, November 24th, 1915.

[2] Lœwenstein (*Münch. Med. Woch.*, 1916, No. 39) describes a suture of the radial nerve performed fifteen days after its division. On the tenth day after the operation, the power of movement was completely recovered; on the thirty-seventh day the electrical reactions were normal.

the nerve in which the process of repair is most rapid ; function is sometimes recovered in four or five months. The ulnar nerve regenerates slowly. The internal popliteal and the median are the most deceptive in their results.

Lastly it should be remembered that the electrical signs of regeneration appear more rapidly in patients who have undergone physiotherapeutic treatment immediately after suture.

It is usually said, on the authority of Duchenne (of Boulogne) that in nerve regeneration, the power of voluntary movement is recovered some time before the electrical reactions reappear.

Stated in this way, the proposition is correct, but incomplete.

Duchenne actually wrote : " I should say at this point that in my experience electro-muscular contractility has always returned, but not completely, and always at a shorter or longer interval after the recovery of voluntary movements and muscular nutrition." [1]

We know now that *the return of faradic excitability of the muscle* is normally *preceded by the return of the faradic and galvanic excitability of the nerve.* " At a certain stage in regeneration," writes Erb,[2] " the faradic excitability of the muscle reappears and gradually approaches the normal. *This usually occurs*

[1] Duchenne (of Boulogne), *Électris. local.*, éd. 1872, p. 372.
[2] Erb, *Traité d'Électrothérapie.* Trad. Rueff., 1884.

rather later than in the case of the nerve, and is also separated by a rather longer interval from the recovery of voluntary movement."

In the nerve, excitability almost invariably returns later than the normal tone, the sensitiveness of the muscle to the faradic current,[1] and even voluntary movement. The nerve first becomes excitable by

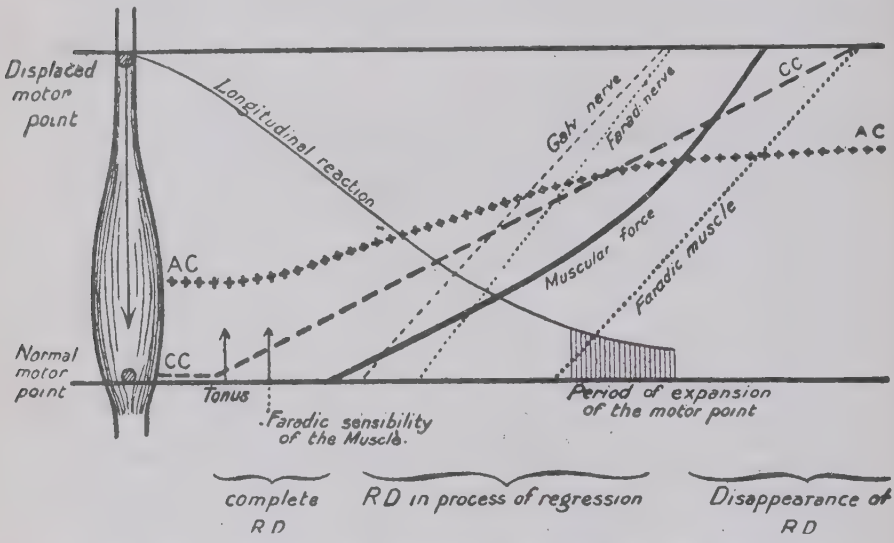


FIG. 41.—Diagram of regressive changes in the electrical reactions (Chartier).

the galvanic current, and some time afterwards by the faradic current (single shocks); stimulation produces a brisk contraction in the muscles which it supplies.

The testing of the nerve should not be confined

[1] Duchenne (Électris. localisée, *passim*) writes: "The faradisation of a nerve or muscle in the normal state always produces a contraction and a sensation. A nerve lesion must be severe to cause complete loss of sensibility in a muscle. . . . The return of electrical sensibility in the muscles is a favourable sign."

solely to points below the lesion; early reactions may be given by stimulation *above* the point of division or compression.

During experiments on the frog at a very early date, Erb observed that injured nerves in process of regeneration regained conductivity before excitability, the nerve being inexcitable below the lesion but excitable above it.[1]

Claude, Vigouroux, and Dumas,[2] record two cases of compression by sclerosis in which they tested the reactions directly during an operation, and found that the excitability of the nerve, which was abolished above the seat of compression, had reappeared some minutes after the nerve was freed from the fibrous tissue enclosing it.

Cottenot and Reinhold have shown that in some cases, when the nerve is still inexcitable below the lesion, a contractile response may be obtained by stimulation above the lesion with the faradic (single shocks) or with the galvanic current. In a case in which excitability had returned in both segments of the injured nerve, they obtained a muscular response with a weaker current in the upper segment than in the lower. According to Cottenot and Reinhold, the return of electrical conductivity in the segment of the nerve above the lesion is always a favourable sign.[3]

[1] Erb, *Arch. f. klin. Med.*, 1868, p. 535.

[2] Claude, Vigouroux, and Dumas, "Cent cas de lésions traumatiques des nerfs des membres," *Presse Médicale*, March 4th, 1915.

[3] Cottenot and Reinhold, "Une réaction particulière observée au cours de la régénération des nerfs," *Bull. Acad. Méd.*, March 28th, 1915.

In the muscle, faradic excitability reappears after a variable length of time; it is usually subsequent to the return of excitability in the nerve, and always remains less than the normal. Galvanic excitability tends to reappear at the motor point, while the longitudinal reaction diminishes. Hence hypo-excitability becomes less marked. It is not until some time later that the qualitative changes begin to disappear; the contraction gradually becomes more rapid, polar inversion is slowly converted into polar equality, and so on. These changes occur in a definite order which varies with the nerve concerned. The recovery of function coincides with the penetration, by the axis-cylinders, of the degenerated nerve, and consequently the first muscles to return to the normal state are those nearest to the lesion, the process of repair spreading farther and farther until the most distally situated muscles are reached, a clinical picture similar to that of dissociated paralyses.

For a long time after the recovery of voluntary movement, antecedent RD may be detected, as much by a slowness of the contraction or a persisting anomaly in the formula as by faradic and galvanic hypo-excitability.

The delay in the regressive changes of the electrical reactions after the recovery of voluntary movement is sometimes such that the latter may have been complete for several weeks or months without any improvement in the electrical reactions. We have recently seen a case of this kind (radial paralysis)

which certainly exhibited incompatible features, the recovery of function being complete, and the muscular development normal, with which was combined absolute inexcitability.

Exceptions to Duchenne's law are not unknown.

Doubtless a certain number may readily be explained by functional disorders, that is to say by the co-existence of a hysterical paralysis. It must, in fact, be remembered that in organic paralyses, anatomical repair may not be followed by recovery of function.

These cases, however, usually exhibit re-development of the muscles from the atrophied condition, a process consistent with the return of the electrical reactions, and equally in contrast with the absence of voluntary movement.

The cases described by Pierre Marie and Mme. Benisty [1] in which faradic excitability or early signs of it reappeared several weeks or months before the return of voluntary movement, are less simply explained. It follows from the observations of these authors that excitability does not always reappear earlier in the nerve than in the muscle. They even discovered cases in which the faradic excitability of the muscles underwent daily variations, disappearing one day to return some days later, and sometimes even

[1] Pierre Marie et Mme. Ath. Bénisty, "Du retour de la contractilité faradique avant le rétablissement de la motilité voluntaire dans les muscles paralysés, à la suite des lésions des nerfs périphériques," *Soc. de Neur.*, April 15th, 1915, and May 6th, 1915.

disappearing exactly at the time when voluntary movement was recovered.

These contradictory phenomena are partly explained by a difference in technique, for instead of using, like Duchenne, the current from a coil of coarse winding, in the form of a tetanising current, these authors employed single shocks from a coil of fine winding, with the maximum intensity (full approximation). Now single shocks are usually more effective, in the pathological condition, than the tetanising current. Dubois,[1] indeed, went as far as to say that he had never seen a single case of complete RD in which single faradic shocks of sufficient intensity were absolutely without effect.

It is obvious that with the diversity of faradic apparatus in use in laboratories, the results of examinations cannot be consistent. In one case the break wave may be of such a form as to be capable of exciting degenerated muscle; in another, it may be too short to cause contraction.

When the faradic excitability of the muscle is tested exclusively with a coil of coarse winding and the tetanising current, it will always be found that Duchenne's law holds good.

The early return of faradic excitability in the muscle, as investigated by this method, has generally appeared to us to be an unfavourable sign.

On the other hand, we regard as a favourable indication the return of faradic excitability (single

[1] Dubois, *loc. cit.*

shocks) or galvanic excitability in the nerve, where this is not preceded by the recovery of voluntary movement.

Earlier indications are afforded by galvanic testing of the muscles. Bourguignon [1] is of the opinion that in cases of nerve suture, slight changes in the galvanic reactions of the muscle usually precede the recovery of motor function (diminution of longitudinal excitability, and lessening of hypo-excitability with galvanotonus, either at both poles or with the positive pole). Similarly a more brisk galvanic contraction, but slight and lacking amplitude, is a bad sign, the amplitude of the contraction being a function of the number of healthy fibres, and its weakness an indication that a number are degenerated.

The evolution of the galvanic reactions of the muscle could obviously be followed very closely by frequently repeated examinations. Hitherto, however, very few electrologists have undertaken an investigation which depends on the recognition of very slight differences, and in which, therefore, the personal equation tends to play a considerable part.

SOME PECULIARITIES OF DIFFERENT NERVES IN ELECTRO-DIAGNOSIS

Facial Nerve.—Direct injury of the facial nerve by a projectile is rare as compared with injuries of the nerves of the limbs. Tinel does not refer to it in his monograph. We have, however, met a certain number of cases.

When the wound involves one of the terminal branches, either

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[1] Bourguignon, *in* Chiray et Roger, *Soc. Méd. Hop.*, December 8th, 1916.

in the parotid or beyond, the nerve is usually severed, and the branch in question exhibits complete RD.

In other cases the nerve is injured by the projectile in its passage through the temporal bone. This kind of injury may give rise either to limited or to complete facial paralysis. The affected region usually exhibits complete RD.

Facial paralysis is also one of the symptoms of fractures of the skull. The trunk of the nerve is then injured either in the canal in the petrous portion of the temporal bone, or higher up. The electrical reactions usually exhibit the characters of complete RD towards the end of the second week.

The appearance of partial RD following injuries of the skull, is not, however, necessarily a favourable sign, as in facial paralysis *a frigore*. It should always be remembered that an effusion of blood or an organised exudate may cause progressive and permanent compression. Partial RD in such a case is therefore merely an early stage of complete RD, and an equally unfavourable sign.

Pontine Syndromes.—Fractures of the skull and concussions may give rise, doubtless by hæmorrhage in the region of the pons, to Millard-Gubler's syndrome, in which flaccid hemiplegia affects the face on the side of the lesion and the limbs of the opposite side (crossed hemiplegia).

The word hemiplegia would seem at first to suggest that RD would not be present. In this variety of hemiplegia, however, the facial paralysis has a different anatomical cause from that producing the paralysis of the limbs: it should be observed that it involves the upper division of the facial nerve as well as the lower. Since the radicular fibres or nucleus of the facial are affected, it may be classed among the paralyses of the peripheral motor neurone, *i.e.* amongst those in which RD may develop.

The reaction of degeneration may be complete or partial, but here again partial RD is not a favourable sign as in facial paralysis *a frigore*. The prognosis in the lesion of the facial is further of little importance in comparison with the general prognosis.

Radial Nerve.—Of all paralyses of peripheral nerves, radial paralyses have been of most frequent occurrence during the course of the war.

The distribution of RD among the extensor muscles indicates the site of the lesion. The triceps is rarely affected in lesions of the radial alone; paralysis of this muscle is usually associated with paralysis of the deltoid (lesions of the posterior cord of the brachial plexus). The commonest seat of injury to the radial nerve

is the middle third of the arm, whether the cause be direct injury by a bullet or shell fragment, or a fracture of the humerus. In this case the supinator longus is included in the group of muscles paralysed. At the same time, it may remain unaffected in radial paralyses following fractures of the lower extremity of the humerus. The extensor carpi radialis longus and brevior may also be unaffected.

Dissociated paralyses amongst the extensors are rare.

In paralyses by compression (compression by a callus of the humerus, crutch paralysis, paralysis following a dislocation of the shoulder, etc.) RD may be partial or total. Its degree varies with the nature, degree, and duration of the compression. Marked RD is a grave sign, particularly when accompanied by advanced muscular atrophy. According to Pierre Marie and Mme. Bénisty, the radial is the nerve which loses its faradic excitability most readily; the electrical reactions may be absent even with a slight anatomical lesion.

It has always seemed to us that modifications of the electrical excitability, whether qualitative or quantitative, can be detected most readily in the extensor carpi ulnaris. In cases of doubt as to whether the contractions are slow, it is a good plan to test at the motor point and point of junction of tendon and muscle.

In traumatic radial paralyses which recover, the process of repair not infrequently fails to include the extensor pollicis longus, both as regards voluntary movements and electrical reactions.

Cases of slight radial paralysis occur, without marked or even in any way evident changes in the electrical reactions, as evidenced by unipolar faradisation of the postero-superior part of the forearm. Stimuli spread by diffusion to the flexors, and the action of the latter overcomes that of the extensors, of which the excitability is less (Babinski).

Median Nerve.—Paralyses of the median are not infrequently dissociated: a lesion of the nerve in the arm or at the bend of the elbow may produce a paralysis of the flexors only, leaving the pronator teres and the palmaris longus and brevis almost unaffected. In Tinel's view, this dissociation is not absolutely diagnostic of a partial lesion, since the median receives a branch from the musculo-cutaneous in the arm.

A lesion of the median in the forearm is generally evidenced by partial or total RD in the muscles of the thenar eminence. Here the abductor pollicis brevis must be made the standard, since the deep portion of the flexor brevis is supplied by the ulnar nerve, and may consequently respond to the faradic current by reactions

suggesting only partial RD, in cases where the median is seriously injured.

The regeneration of the median is always slow; the abductor brevis is the last muscle to recover, and its function is rarely altogether restored.

Babinski calls attention to the fact that in paralysis of the median, stimulation of the biceps produces a movement of more marked supination than normally, owing to the absence of the antagonistic action of the pronator teres.

In slight median paralyses without appreciable change in the electrical reactions, when bipolar faradisation of the forearm produces flexion, monopolar faradisation by application of an electrode in the antero-inferior part of the forearm causes a paradoxical extension of the hand, owing to diffusion of the current to the extensors, which are relatively more excitable (Babinski).

In testing the muscles of the palmar aspect of the hand, it is well, in order to avoid causing the muscles of the forearm to contract, to place the indifferent electrode on the dorsum of the hand.

Ulnar Nerve.—Complete paralysis of the ulnar may easily be missed in a superficial clinical examination, in cases where simple compression or recent severance is the causative lesion, owing to the fact that numerous other muscles supplement the actions of those controlled by this nerve, with the result that almost all movements of the hand are still possible.[1] The importance of changes in the electrical reactions in such a case is evident.

Discrepancies between clinical facts and the electrical reactions seem fairly common in lesions of the ulnar. Thus in even slight compressions of the nerve in the region of the epitrochlear sulcus, which forms an inextensible canal, complete RD follows in some cases, either throughout the region supplied by the nerve, or more locally, and sometimes only in the interossei and the hypothenar eminence.[2]

In a case of Goldmann's,[3] with a tumour of the elbow involving the ulnar, resection of 5 cm. of this nerve produced neither motor

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[1] The exception is that the last two fingers cannot be brought together. Loss of adduction of the little finger is often the only apparent sign of a complete ulnar paralysis. It is the only movement which cannot be effected in any other way (Tinel).

[2] Sicard and Gastaud, "Les névrodocites," *Soc. Méd. Hop.*, November 3rd, 1916.

[3] Goldmann, *Neurol. Zentralbl.*, 1906.

nor sensory paralysis. The electrical reactions were similarly found to be unchanged.

Are cases of this kind to be explained by the anastomotic branch from the median ?

Further, we have particulars of a case of simultaneous paresis of the median and ulnar, which exhibited partial RD only ; no improvement occurring, an operation was performed, and the ulnar was found to be completely severed, with a neuroma at the proximal end of the nerve.

Here again, to explain only partial RD in spite of section of the nerve, is the branch from the median to be regarded as playing some part ?

Brachial Plexus.[1]—The brachial plexus may be injured in wounds or their sequelæ, by a projectile, a hematoma, a fracture, a callus, by the formation of scar-tissue, etc. Paralyses of the brachial plexus may also follow injuries to the shoulder, contusions, a fall on the shoulder, depression of the shoulder in structural collapse, dislocations of the shoulder, and manipulation in reduction.

Three varieties are usually distinguished : an upper radicular type (Duchenne-Erb type) from injury of the Vth and VIth cervical nerves, a lower radicular type (Klumpke's type) from injury of the VIIth and VIIIth cervical and Ist thoracic nerves, and lastly, a total radicular type. Sometimes the paralysis is definitely limited to the region of peripheral distribution corresponding to these nerves, and sometimes, on the other hand, the distribution of motor disorders, and more particularly an electrical examination, go to show that the actual distribution of radicular paralyses varies more or less from these fundamental types ; paralyses are not definitely localised in the upper and lower regions, and in other cases the two regions, though simultaneously affected, are affected in different degrees.

The electrical reactions usually develop into complete or partial RD ; very occasionally only faradic and galvanic hypo-excitability appear.

The distribution of RD indicates the radicular region concerned more precisely than is possible by clinical observation, since an investigation of the power of voluntary movement of certain muscles (infraspinatus, teres major, etc.) is almost impossible, and further, on the borders of this region it is not unusual to detect traces of RD in muscles which appear functionally unimpaired.

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[1] Cf. A. Zimmern, " L'électrodiagnostic dans les paralysies radiculaires du plexus brachial," *Paris médical*, 1911.

The problem of the exact localisation of the lesion is extremely complex. Thus in a case of upper radicular paralysis there may be some doubt as to whether the causative lesion is intra- or extra-vertebral. In such cases the reactions of the serratus magnus may give valuable indications. The nerve to the serratus magnus is given off, almost constantly, at the points of exit of the cervical nerves from the intervertebral foramina. The existence of changes in its reactions would therefore indicate a lesion situated higher up. Suture being impossible unless the lesion is extra-vertebral, the importance of testing the reactions of the serratus magnus will readily be understood.

When RD exhibits a complex peripheral distribution, corresponding neither to the peripheral distribution of the terminal nerves nor to the actual radicular distribution, and when the oculo-pupillary syndrome, indicating a lesion near the intervertebral foramen for the first thoracic nerve, is also absent, a lesion in the network of the plexus is suggested. A definite conclusion, however, cannot be drawn, as several solutions are possible ; an unequal distribution of RD may, in fact, be observed when there are co-existing lesions of several roots.

In spite of these difficulties, careful testing of every muscle, rigorous classification of the muscles according to the degree of change in the electrical reactions, and finally systematic interpretation, will often enlighten the surgeon as to the probable seat of the causative lesion.

The peripheral distribution of the five roots forming the brachial plexus will be found tabulated on page 149 : we have only included muscles supplied by terminal or collateral branches which, owing to their superficial situation, are directly and easily accessible to the testing electrode.

Prognosis.—It may be stated as a principle that any traumatic radicular paralysis accompanied by RD, or even by partial RD, is always grave.

Only radicular paralyses unaccompanied by RD suggest a favourable prognosis or can rightly be regarded as benign. In these cases rapid return of function is the rule, and recovery is almost always complete.

The exceptionally grave prognosis in the case of partial RD and the frequent occurrence of forms exhibiting the syndrome of degeneration, give radicular paralysis a particularly grave character unparalleled in affections of the same order. As Huet has pointed out, it would appear that the prognosis in traumatic paralyses of the brachial plexus is more unfavourable for a lesion of

Spinal Roots.	Distribution of the Nerves						
	Musculo-cutaneous.	Circumflex.	Collaterals.	Collaterals.	Radial.	Median.	Ulnar.
Vth Cervical.	Biceps. Brachialis anticus.	Deltoid. Teres minor.	Rhomboids.	Infraspinatus. Teres major. Pectoralis major. Serratus magnus.			
VIth Cervical	Biceps. Brachialis anticus.	Deltoid. Teres minor.		Infraspinatus. Teres major. Pectoralis major. Serratus magnus.	Supinator longus. Triceps (?).		
VIIth Cervical.				Teres major. Pectoralis major. Serratus magnus. Latissimus dorsi.	Triceps. Extensors. Ext. carpi ulnaris. Ext. Carpi. Rad. Long., and Brev.	Pronator Teres. Palmaris longus. Flexors. Thenar Eminence.	
VIIIth Cervical.				Pectoralis major. Latissimus dorsi.	Triceps.	Flexors.	Flexor carpi ulnaris. Hypothenar. Interossei. Adductor pollicis.
1st Thoracic.				Pectoralis major.		Flexors.	Flexor carpi ulnaris.

given severity, than in traumatic paralyses, as a whole, of peripheral nerves. "The course of radicular paralyses is almost that of myelitis." The peculiar gravity of radicular paralyses is undoubtedly explained by the extension of the injury to the cord, by the more or less severe effects of the causative lesion on the motor cells (traction, concussion, or compression). As Mme. Déjerine has shown, the lesion in lower radicular paralyses may consist in a tearing away of the nerve roots from their points of origin in the cord.

In cases progressing favourably, the circumflex and musculo-cutaneous nerves are the first to regenerate, followed by the radial, then the ulnar, and finally the median. RD undergoes regressive evolution, and after 5, 6, or 8 months the patient ends by recovering the use of his limb fairly completely, but recovery is more usually only partial, and the functions of the upper limb remain very seriously impaired.

Sciatic Nerve.—Lesions of the trunk of the sciatic are not infrequently dissociated: the level of the bifurcation of the nerve is extremely variable, and is sometimes even at the point of exit from the greater sciatic foramen. The size of the nerve trunk is such that some of its fibres may be injured to the exclusion of the rest, and it is not uncommon to see a complete paralysis of the region supplied by the nerve, subsequently persisting in the region supplied by one of the branches, but exhibiting signs of progressive regeneration in the other.

The external popliteal in its course round the head of the fibula is equally vulnerable by external traumatic agents (projectiles) and by internal agents (fracture of the head of the fibula, or a callus, etc.). A frequent cause of permanent compression liable to produce more or less complete paralysis, and often unrecognised or even attributed to hysteria or simulation, is strangulation by the tibialis anticus or peronei. This form of paresis is almost invariably characterised by partial RD.

SOME ANASTOMOSES AND MIXED OR ABNORMAL INNERVATIONS OF IMPORTANCE IN EXPLAINING THE COEXISTENCE OF CERTAIN VOLUNTARY MOVEMENTS WITH ABNORMAL ELECTRICAL REACTIONS

Mixed Innervations.—The flexor digitorum profundus is supplied both by the median and the ulnar.

The flexor pollicis brevis consists of two parts: the superficial part receives a branch from the median, and the deep part is innervated by the ulnar.

The rhomboids are supplied by a branch from the cervical and a branch from the brachial plexus.

Abnormal Innervations.—The flexor carpi ulnaris is sometimes supplied by the median. The adductor pollicis is sometimes supplied by the median (Froment). The abductor pollicis brevis sometimes receives fibres from the superficial branch of the radial (Lejars).

Brooks has described cases in which the deep branch of the ulnar supplied the flexor pollicis brevis, the opponens pollicis, and the abductor pollicis brevis.

The musculo-cutaneous occasionally takes the place of the median in supplying the pronator teres.

In a case of Turner, the ulnar supplied neither the flexor profundus nor the flexor carpi ulnaris, but sent a branch to the flexor sublimis.

Anastomoses.—*Musculo-cutaneous-median.* Situated in the middle part of the arm; represents a part of the plexus which would complete the distribution of the radicular fibres between the median and the musculo-cutaneous.

Median-ulnar.—(*a*) in the arm: a branch passing behind the brachial artery (Villar); (*b*) in the forearm: a branch consisting of two or more filaments passing in front of the flexor profundus and deep to the flexor carpi ulnaris; its function appears to be to complete the double innervation of the flexor profundus by the median and ulnar.

II. Lesions of the Cord

Cases of compression and partial or complete severance of the spinal cord, whether by the direct action of a projectile or complicating a fracture of the vertebral column, are of frequent occurrence in war pathology.

The changes in the electrical reactions which accompany these lesions principally affect the lumbar and sacral regions, where they may be unilateral or bilateral, symmetrical or diffuse, systematic or dis-

sociated. In lesions situated higher up they may also develop in the upper limbs. In one case of section of the cord, Bastian detected no changes in the electrical reactions. The majority of authors, however, who have had occasion to study cases of this kind, describe very marked hypo-excitability to both forms of current, with or without slowing of the galvanic contraction, and often even absolute inexcitability (Schultze, Pfeiffer) in the whole of the region involved in the paraplegia. Marked hypo-excitability seems to have been a more constant feature than RD itself. According to Brun,[1] this hypo-excitability is only apparent, being due to presence of considerable œdema.

Pierre Marie and Foix regard the changes in the electrical reactions as resulting, at least in a number of cases, from a neuritis in the affected limbs, usually most marked in the external popliteal nerve.[2]

A study of the alterations in electrical reactions is of no great value in direct injuries to the cord, unless, as in some cases, its purpose is to determine the level of the lesion, and hence to verify a radiographic examination.

Much more valuable information may be gained by testing the reactions in contusions of the cord (falls, burying, or the impact of a projectile), and concussions by shell or mine explosion.

Paralyses following injuries of this nature are often

[1] Brun, *Arch. f. psych.*, 1893.

[2] P. Marie and Foix, *Soc. de neurol.*, March 2nd, 1916.

accompanied by a slight or marked degree of RD, attributable to lesions of the anterior horns (hematomyelia).

In severe cases, hematomyelia is clearly evidenced by a number of characteristic clinical symptoms (paraplegia and syringomyelic dissociation), but in the less severe forms, the discovery of abnormal reactions ranks, with lumbar puncture, as of the greatest diagnostic value.

In mild cases, where the supplementary action of other muscles is liable to mask the paralysis, one muscle or a group of muscles on one side or both, usually in the region of distribution of the sciatic, and more particularly in that of the external popliteal, will be found to exhibit either a mere diminution of excitability or partial or complete RD.

Since changes in the anterior horns may affect the grey matter at different levels, the corresponding changes in the electrical reactions may appear in a number of widely separated muscles of altogether different groups.

The degree of RD is usually a sure indication of the prognosis : cases where only a limited number of muscles are involved, and RD is only partial, usually recover without difficulty.

III. Combined Hysterical and Organic Disorders

The clinical symptoms in wound cases not infrequently fail to correspond with the classical descriptions of peripheral paralyses. When a nerve lesion is

complicated by direct injury to muscles, or when joints, and particularly small joints, have become stiff owing to prolonged immobilisation, the loss of function will appear greater than the nerve lesion itself can account for. It will readily be understood that electrical examination is of great value in such cases in determining the extent of the part played by the nerve lesion in producing these symptoms.

In other cases the simultaneous injury of several nerves, each giving rise to a different paralysis, will render the clinical diagnosis extremely laborious. It seems hardly necessary to emphasise the value of an electrical examination, not merely from the diagnostic point of view, but also in determining the degree of severity and probable nature of the lesion in each case.

The same is the case with superimposed psychical paralyses, which sometimes so strangely transform the clinical picture in an organic paralysis.

It is not unusual, for instance, to find a patient with an organic lesion of the ulnar and median nerves unable to raise the wrist or extend the fingers.

Sometimes these additional paralyses are immediate, following directly on the injury; sometimes they develop gradually, particularly when the patient is kept at rest for a long time, and care has not been taken to correct the more powerful action of antagonising muscles by means of suitable elastic appliances.

In every case, the absence of pathological reactions, contrasting with the severity of functional disorder

observed clinically, will indicate the real cause of the paralysis. It should not, however, be forgotten that the diagnosis can only be made with certainty after an interval of about ten days, that is to say, until sufficient time has been given for early anomalies of the reactions to develop.

IV. Reflex Paralyses and Contractures (Physiopathic Disorders)

The preservation of the normal electrical reactions in functional disorders of a hysterical nature is now an established fact, and consequently a factor of the greatest importance in diagnosis.

Certain cases have, however, been described in the past, rather as curiosities, of functional disorders which gave rise, either merely to a slowed contraction or to partial RD, and such observations were regarded with incredulity by those who had not actually observed these phenomena themselves. Possibly these paradoxical reactions may be explained by a study of the physiopathic disorders appearing during the present war.

It will be remembered that Babinski and Froment have established the relationship between the disorders which they describe as paralyses (and contractures) of a reflex nature, and the amyotrophic reflex paralyses first studied by Charcot and Vulpian.

The variety known as articular or abarticular, which follows injuries or inflammations of joints, is the commonest type. It is well known to medical

electrologists, possibly more so than to surgeons and neurologists, since the patient usually comes direct to an electrologist to be relieved of this persistent functional trouble.

Quantitative changes in excitability are the only abnormalities in electrical reactions occurring in these articular amyotrophies. The reaction of degeneration is never present. Faradic and galvanic excitability are more or less diminished, in some cases preceded by a stage of faradic hyper-excitability (Mally). Not infrequently excitability to the galvanic current is more markedly reduced than to the faradic. Evidence of this diminution of excitability is shown, not merely by a higher threshold, but by reduced amplitude of the maximal contraction.

According to Mally, the prognosis in reflex articular atrophy depends on the extent to which the galvanic excitability of the muscle is diminished, an increase in galvanic excitability being a favourable sign.

We should also emphasise, in passing, the importance of testing the electrical reactions in the particular type of paralysis following injuries to the shoulder (fractures of the neck of the humerus, dislocations, etc.). These are often diagnosed as reflex atrophy. The presence of the reaction of degeneration will indicate their true causation—neuritis of the circumflex nerve, compression, or more or less extensive lesions of the spinal nerve roots.

Since the beginning of the war, physicians have

often been struck by the number of atypical disorders, exhibiting neither the features of hysterical manifestations nor those of organic nerve lesions.

Owing largely to their novelty, these conditions have been investigated by a number of workers, and a particularly good description of them has been given by Babinski and Froment.

Amongst their distinctive features, together with *mechanical hyper-excitability of the muscles and the slowness of the contraction excited by percussion*, Babinski and Froment describe two electrical signs—*slight hyper-excitability or hypo-excitability*, and *premature fusion of contractions*.[1]

The quantitative abnormalities on faradic stimulation are never pronounced ; sometimes the difference between the healthy and affected sides is so slight as to suggest that quantitative changes have not occurred.

When they are evident, steps should be taken to show that they are not merely apparent, and due to increased or reduced skin resistance on the affected side. We have often observed a marked alteration in skin resistance in reflex paralyses and contractures.

We have already indicated [2] that cold alone may modify the character of the galvanic contraction, and that its action is indirect, through the circulatory disturbance which it produces. It would therefore be reasonable to expect a slowed contraction in reflex disorders accompanied by hypothermia and vaso-

[1] Babinski and Froment, *Hystérie. Pithiatisme et troubles nerveux d'ordre réflexe*. Paris, Masson, 1917.

[2] See p. 77, Sources of error in deducing RD.

motor paralysis. We are inclined to go further in explaining the phenomenon, and to suggest that it may also be produced by asphyxia, CO_2 poisoning, a sluggish circulation, and imperfect exchange between the blood and the tissues.

The changes in excitability and the character of the muscular contraction can be determined most readily in the small muscles of the hand (thenar and hypothenar eminences and interossei).

Faradic excitability is sometimes slightly increased, sometimes slightly diminished. The contractions produced by single shocks may appear fairly brisk, but it will often be found that the number of stimuli per second which will produce tetanus is lower than in the case of a healthy muscle of approximately equal size. This phenomenon of premature fusion of contractions (Babinski and Froment) is therefore indirectly indicative of slow faradic contraction.

With the galvanic current, excitability may be increased or diminished in different cases; the contraction is sometimes markedly and sometimes only slightly slower than the normal.

Artificial cooling of a limb produces slowing of the contraction; if then it be adequately warmed, the contraction becomes more rapid and finally normal.

All these abnormal phenomena originate in disturbances of temperature, and disappear with them. Increased rapidity of contraction on warming will always distinguish these reactions from the reaction of degeneration.

V. Ischæmic Paralyses

Local anæmia may produce marked changes in the electrical reactions. These were demonstrated by Marey, who observed slowing of the contraction after ligature of the artery supplying the muscle.

The effects in man are variable ; sometimes typical RD appears, but it is commoner to find a remarkable degree of hypo-excitability, amounting sometimes to inexcitability, with or without polar inversion. This inexcitability of the muscles is often earlier and more pronounced than the inexcitability of the nerve supplying them (Tinel).

The electrical reactions are also more or less markedly altered in certain pathological conditions of common occurrence during the present war, which have been compared with Volkmann's ischæmic contracture (pain, œdema, hypothermia, wooden hardening of the muscles, fibrous retractions).

Any condition intermediate between simple hypo-excitability and complete RD may be present. Further, the distribution of these effects is extremely irregular ; one muscle may exhibit complete RD and its immediate neighbour simple hypo-excitability. In the small muscles of the hand, testing the reactions is an easy matter ; in the flexors, however, retraction and fibrosis may render it entirely impossible.

The anomalous electrical reactions in Volkmann's syndrome are sometimes attributed to ischæmia, but it seems much more logical to attribute them either

to a neuritic process connected with the muscular changes, or simply to strangulation of the nerve fibres in masses of fibrous tissue.

VI. Paralyses of Toxic and Infective Origin. Non-traumatic Forms of Neuritis, Myelitis, etc.

Paralyses due to infective or toxic neuritis are as common in military ambulance stations and hospitals as in civil practice. We shall therefore describe the essential features of electro-diagnosis in each type of case.

Peripheral Facial Paralysis.—Facial paralysis *a frigore*, an extremely common condition, may assume either of two forms, the benign or the severe. Although the severe form may not be followed by permanent paralysis, its effects will render the patient unfit for further service, particularly when lachrymation interferes with vision, and inability to close the eye leaves the conjunctiva unprotected.

It is impossible to distinguish clinically between the slight and severe forms. There is nothing in the clinical signs of facial paralysis *a frigore* to suggest whether the lesion is severe or otherwise, or its probable duration.

Electrical methods are the only means of obtaining this information. Erb, in fact, showed that from the results of an electrical examination, any given case could be classed in one of the following categories—

mild form, intermediate form, and severe form, the course and prognosis being different in each case.

1. In the *mild form* of facial paralysis, the electrical reactions remain normal. The outlook in these cases is always favourable, and recovery usually takes place within *three weeks*. Unfortunately a relatively small proportion of cases assume this form.

2. In the forms exhibiting RD, the quantitative and qualitative changes preceding the appearance of definite RD (complete or partial) usually develop during the first two weeks. These changes are only slight for some days, and, as a rule, the abnormal reactions only begin to take definite shape towards the end of the first week; the development of RD is not complete until *the thirteenth or fourteenth day*.

It will therefore be obvious that an examination at an earlier period, finding the muscles in the stage of diminishing faradic excitability, will furnish no definite indication as to the form of the paralysis. Hence the rule that *no conclusions* as to the severity or prognosis in a case of facial paralysis should be drawn *before the end of the second week*.

The essential and remarkable characteristic of the progress of RD in facial paralyses is *prolongation of the stage of galvanic hyper-excitability*.

(*a*) The *intermediate form* is distinguished by the presence of partial RD.

As in the first variety, recovery is usual in the intermediate form, but the process is a longer one. The return of voluntary movement usually begins at

about the second month, and *recovery is not complete until three to six months* have elapsed. The electrical reactions remain abnormal for much longer periods, regressive changes beginning long after the power of voluntary movement has been recovered.

(*b*) The *severe form* is characterised by the presence of complete RD.

The prognosis is always unfavourable. Recovery, if it takes place, is very rarely complete. Traces of the paralysis usually persist in the form, either of slight paresis, evident in any change of facial expression, or of a certain asymmetry of the face, often the more evident owing to some slight degree of contracture. The first voluntary movements in these cases usually appear *between the third and the tenth month.*

The recovery of voluntary movements often precedes the return of the electrical reactions to the normal by a long interval, and many months elapse before the muscles regain their faradic excitability. Sometimes the regressive evolution of RD is so slow, and faradic and galvanic excitability remain diminished for so long, that an examination of old facial paralyses which have recovered will often reveal a marked reduction in both forms of excitability and obvious traces of slowed contraction, long after clinical improvement has ceased.

When voluntary movements fail to reappear within ten months, the likelihood of recovery becomes very doubtful.

In incurable cases, a considerably prolonged stage

of galvanic hyper-excitability is followed by a period of *progressive hypo-excitability*; the muscular response becomes more and more difficult to elicit by galvanic stimulation. If inversion of the formula has not occurred earlier, it will appear at this stage; at first ACC = KCC, and later the AC contraction becomes greater than the KC.

In many cases *the reaction of exhaustion* will also be detected by galvanic excitation. Repeated galvanic stimuli at short intervals provoke contractions which become progressively weaker.

The incurable forms sometimes end in atrophy of one side of the face, but a much more common result is permanent secondary contracture. This condition only occurs as a sequel to the severe forms exhibiting complete RD. It usually begins to appear during the third or fourth month, and is at first localised in the zygomaticus, extending thence to the levator labii superioris alæque nasi, drawing the labial commissure upwards and outwards. This contracture is sometimes transitory, but more often permanent and intractable. It is an almost invariable sequela in older individuals, and in cases where the general condition is poor at the time of onset.

The following signs indicate the approach of this condition:

1. Spasmodic contractions, occurring either spontaneously, or as the result of artificial stimuli (electrical, or percussion).
2. The rapid recovery of tone when voluntary movement is still impossible.
3. The return of faradic excitability in the muscles in an unusual order (Duchenne).

Duchenne gave the following as the order in which the muscles recover their excitability, in curable forms: buccinator, zygomatici, levator labii superioris alæque nasi, frontalis, orbicularis oculi, and lastly the dilatores nasi.

4. The appearance of certain associated movements: if the patient is told to close his eyes tightly, there is a simultaneous upward and outward movement of the labial commissure and the ala of the nose (Huet). Similarly the palpebral fissure is narrowed when the patient attempts to smile.

The *entire absence of clinical signs* to indicate the severity of a case of facial paralysis, lends additional importance to the results of electrical examination, as we have already seen. Electrical methods, however, although they may determine the diagnosis of a severe form, cannot decide the prognosis. There is nothing in the reactions to indicate beforehand whether the paralysis will pass off or remain permanent, or what degree of contracture is to be expected.

Facial paralysis is common in *infective otitis*. It commonly affects the upper and lower divisions unequally, and is more usually confined to the lower, in which its effects become more or less marked. In all long-standing cases of suppurative otitis there is slight deviation of the labial commissure, the only sign of paresis of the lower division of the facial nerve (Moure).

These pareses or paralyses are usually accompanied by partial RD, and the changes in the reactions are always less marked in the upper part of the face; in total paralyses, this sign is the earliest indication of an improvement.

Otitic facial paralysis with complete RD is generally the result of purulent otitis, mastoid abscess, or caries of the temporal bone ; it has also been known to follow surgical trauma in operations on the ear (curetting and trephining of the mastoid, etc.).

Here again complete RD is a serious sign, and indicates an unfavourable course ; all facial paralyses accompanied by complete RD are not, however, incurable.

Radial Paralysis. — Common radial paralysis, described as radial paralysis *a frigore*, is most commonly caused by compression and stretching of the nerve (pressure against the edge of a table, or upon the operation table during general anæsthesia, against the back of a chair in individuals who fall asleep in this position, or against the humerus in persons who sleep with the arm bent beneath the head, and so on).

In such cases the nerve is subjected to pressure, but only for a short period, whereas in paralyses by compression (the pressure of a callus or a crutch, etc.), the cause of compression is permanent, progressive, or renewed at intervals indefinitely.

The electrical excitability in radial paralysis *a frigore* undergoes very little change ; a slight reduction in the faradic excitability of the muscles, unaccompanied by changes in the galvanic contraction, is the only anomaly liable to occur.

Cases have certainly been reported of radial paralysis from compression during sleep, which were accom-

panied by signs of RD. These are, properly speaking, exceptions which in no way invalidate the rule, and can be explained on the grounds that the nerve has to some extent absorbed a toxic substance, generally alcohol. Radial paralysis of this type in drinkers certainly occurs much more commonly in a drunken sleep than otherwise.

In common radial paralysis, stimulation above the point of compression, as we have already seen, may suggest false conclusions as to the electrical reactions. The conductivity of the axis-cylinder is often abolished below the point of compression, so that faradic stimulation in the axilla causes no contraction of the extensors of the hand, but may provoke contraction of the triceps, the nerve to which arises above the point of compression.

The existence of faradic excitability may be demonstrated by applying the electrode below this point (Erb).

Radicular Paralyses of the Brachial Plexus.— Radicular paralyses result either from lesions of a surgical nature (stretching, rupture, and compression of the nerve roots) (see p. 147), or from inflammatory changes, or from some toxic cause. The second category includes paralyses due to involvement of the spinal roots in inflammations of the meninges (cerebro-spinal and other forms of meningitis), in addition to primary affections of the nerve roots.

Radiculitis and the radicular paralyses of meningitis

are accompanied in their course by complete or partial RD or merely by diminution of excitability to both currents, according to the degree of severity of the lesion. The reactions develop slowly or rapidly, according as the disease is chronic, subacute, or acute. When the abnormal reactions have fully developed, and are found to be definitely characterised in one of the radicular regions of distribution (upper, lower, or both), the limits of this region will not be clearly defined; various muscles are unequally affected, some exhibiting total and others partial RD. Sometimes the topography of the reaction is so irregular that it becomes scarcely recognisable as a radicular distribution.

This is explained by the fact that different roots may be affected unequally.

The distribution of the electrical reactions is not usually sufficient in itself to distinguish between acute poliomyelitis localised in the upper limb segments, and radicular inflammation. In both cases the disease may spread beyond the cervical region, and paralytic disorders, with altered reactions, may be observed in the intercostal muscles and the lower limbs, or on the opposite side.

From the point of view of recovery of function, RD is not as serious a sign in radiculitis as in poliomyelitis.

Disappearance of the signs of inflammation, and good results from treatment in the syphilitic forms, give some hope of recovery; but granting that the

radicular lesions are capable of repair, functional recovery is usually imperfect, and never as satisfactory as in peripheral neuritis, for example. It may be stated in a general way that from the point of view of its significance in prognosis, RD in radiculitis stands intermediately between RD in poliomyelitis, and RD in multiple neuritis.

Sciatica.—Sciatica *a frigore*, or from a toxic or infective cause (syphilis, gonorrhœa, tuberculosis, gout, etc.), if accompanied by functional impairment or muscular atrophy, always presents some degree of change in the electrical reactions, which finally may amount to complete RD.

Intermediate between sciatic neuritis with trophic disorders, and simple sciatic neuralgia, are a large number of cases in which the electrical reactions are not customarily tested.

According to Néri, faradic and galvanic excitability are often diminished, more notably in the internal than the external popliteal nerve.[1]

This difference is further shown by diffuse faradic excitation of the sole of the foot, which in certain cases of sciatica causes extension of the toes, instead of producing flexion, as would be the case normally.

Multiple Neuritis.—Infective multiple neuritis (in influenza, typhoid, diphtheria, typhus, leprosy, and

[1] V. Néri, "Les petits signes électriques de la sciatique," *Bull. delle Sc. med.*, February 1917.

beriberi) and toxic multiple neuritis (alcoholic and syphilitic) have been met with frequently in the course of the war.

Except in rapidly curable forms of alcoholic paraplegia and generalised diphtheritic paralysis, RD is the rule in multiple neuritis. In many cases it is even developed earlier than the first manifestations of paralysis.

RD possesses a definite character in multiple neuritis, and accurately reflects the histological changes occurring in the nerves. In the first place, its extent and distribution among a large number of muscles belonging to different groups indicate the multiplicity and widespread distribution of the nervous lesions. Further, its variations in degree from one region to another, or from one muscle to another, reflect the irregularity and diffuse nature of the anatomical process. It usually does, in fact, appear in different degrees; one muscle may exhibit complete RD, and another, supplied by the same nerve, only partial RD, or possibly complete RD with less marked diminution in galvanic excitability. Certain cases show only partial RD, but almost always with the same obvious differences in the extent of diminution of faradic excitability.

It is not unusual in multiple neuritis to find that the extent of the paralysis and the degree of alteration in the electrical reactions are far from corresponding. There may be profound changes in the electrical reactions, complete RD, slow contraction,

or absence of faradic excitability, while the muscle responds normally to voluntary impulses.

RD may sometimes be the first indication that neuritis is present. It often happens that no attention is paid to the conditions of weakness in the lower limbs appearing in certain patients, during convalescence from influenza, for instance. Now in cases of this kind, *some traces of RD* will often be detected on electrical examination, and the actual cause of this loss of power will be recognised.

In the same way, a certain difficulty in marching, or a condition of continual fatigue in the lower limbs, should arouse the medical officer's suspicions. An electrical examination will often show traces of RD, which will lead to the discovery of the fact that the patient has been drinking excessively, and incidentally explain the merely subjective symptoms of which he complains.

The degree of severity of multiple neuritis varies, in the first place, with the intensity and the extent of distribution of the anatomical changes in the nerves, and further, with the nature of the underlying cause.

Almost all forms will recover, unless certain of the cranial nerves become involved.

RD is therefore not a peculiarly bad sign in multiple neuritis. A muscle which will only respond to longitudinal stimulation does not undergo atrophy and permanent loss of function, as usually occurs in poliomyelitis.

Alcoholic neuritis more particularly affects the lower limbs, especially the extensor group (quadriceps femoris, extensor digitorum longus, extensor hallucis longus, the peronei, and tibialis anticus). The relative gravity of the prognosis is explained by its long duration, and by the fact that deformity is a common result.

The severity of infective multiple neuritis varies with the degree of RD and the extent of its muscular distribution. In the forms involving a large number of muscles, recovery is always slow, and some of these muscles may remain permanently affected.

Diphtheritic paralysis, a comparatively rare condition, is sometimes accompanied by partial RD (paraplegic forms, and diphtheritic facial paralysis). Complete RD is exceptional. It would therefore appear that the diphtheria toxin has a less severe effect on nerve tissues than other toxic processes.

Multiple neuritis has been observed to follow *frost-bite*, and even *gassing*, during the course of the war.

These forms are usually localised to the extensors of the leg, symmetrical, bilateral, and accompanied by partial or complete RD.

According to Tinel, the tibialis anticus is often unaffected, as is the case with the supinator longus in lead poisoning.

Poliomyelitis.—Poliomyelitis in the adult has appeared several times during the war.

As in infantile poliomyelitis, cases unaccompanied by RD, and ending in spontaneous and complete recovery, are extremely rare.

In the vast majority there are profound changes in the electrical reactions.

Poliomyelitis in the adult is usually less systematised than the infantile form. It has a selective action on the lower limb, but its effects are not confined to the antero-external group of leg muscles. It often affects the thigh or the opposite limb simultaneously, and sometimes also the upper limb.

The differential diagnosis from multiple neuritis is often extremely difficult. Clinically, the mode of onset and the presence of sensory disturbance will leave no doubt as to the nature of the disease. From the point of view of electrical reactions, wide distribution and unequal degrees of RD in adjacent muscles suggest multiple neuritis, and a radicular distribution suggests poliomyelitis. Conclusions have frequently to be based on very slight differences.

The prognosis varies with the extent to which the electrical reactions are modified. The presence and persistence of complete RD, with inexcitability at the motor point, indicate severe degenerative changes in the anterior horn cells, and leave little hope of recovery of function.

Partial RD, on the other hand, indicates that the corresponding cells in the grey matter are less completely involved, and although it is to be feared that the muscle will never recover its original strength

and development, it will certainly not undergo total atrophy.

VII. The Severance of Muscles and Tendons

Gunshot wounds frequently involve severance of muscles or tendons, caused either directly by the projectile itself (a fragment of shell) or by suppurative erosion.

It may be of importance to know what tendon or tendons have been cut, and in this connection electrical methods may be of great service.

Assuming a patient to be incapable of performing a certain definite movement, either the electrical reactions of all the muscles will be normal and stimulation will produce normal movements at the joint concerned, which suggests that the paralysis is psychical in origin; or the reactions will be abnormal, with or without RD, which suggests some form of neuritis; or the reactions will be normal, but muscular contraction will produce no movement of flexion or extension, adduction or abduction, and so on, in which case there is every reason to suppose that the tendon is divided.

In such a case it is best to test with the tetanising faradic current, and the electrodes are applied close together over the fleshy part of the muscle, to avoid diffusion of the current. A series of sustained contractions is produced by means of the key. It will then be observed that contraction of the muscle causes no corresponding movement in the part into which its tendon is inserted, whereas stimulation of adjacent muscles produces movement. The belly of the muscle will be felt to swell beneath the touch, but the finger will not detect any movement of the tendon.

During this examination it is essential to place the limb in such a position that a certain amplitude of movement is possible, a precaution recommended by Duchenne (of Boulogne). To facilitate a movement of flexion at any given joint, the limb must be extended, and *vice versa*.

Further, it is often necessary, as Laquerrière observed, to immobolise certain parts : to be sure, for instance, that the terminal phalanx is being flexed, the second must be prevented from moving, or the whole finger will be drawn towards the palm of the hand, which is no evidence as to the condition of the flexor profundus.

The value of an electrical examination in cases of this kind is enhanced by the fact that ability to execute voluntary movements may conceal the presence of a severed tendon. Muscular groups rather than single muscles are employed in voluntary movements ;

moreover, a divided muscle is always retracted, and it is almost impossible to detect its contraction by touch.

Unfortunately, the proportion of such cases presenting nothing more than simple division of a tendon is much lower in the case of gunshot wounds than in accidents in civil practice.

Ruptured tendons are often embedded in scar tissue adherent to neighbouring structures, which frequently forms a large fibrous mass from which it is impossible to dissect a muscle or tendon.

CHAPTER IV

ELECTRO-DIAGNOSIS IN DISORDERS OF SENSATION AND THE SPECIAL SENSES

I. Disorders of Cutaneous Sensation

Farado-cutaneous Sensibility and Sensibility to Pain.— We have seen that under certain conditions of technique the faradic current is liable to produce marked sensory effects. Using current from a coil of fine winding (current of tension), and an active electrode of metal rather than a moist electrode, the skin being smeared with a thin film of vaseline, sensibility can be tested much more satisfactorily than by using a needle. In the first place, the fact that the skin is not injured by the process enables the operator to repeat stimuli indefinitely without leaving any trace of them; further, the stimulus may readily be graduated and measured by moving the secondary coil; and finally, stimulation can be carried to such a point that all forms of anæsthesia, other than complete organic anæsthesia, can be overcome by the current. With these advantages the faradic coil is a valuable means of testing sensibility, both from the point of view of affections of the sensory system, and for the purpose of exposing malingerers.

When a metallic electrode (Tripier's or Duchenne's brush) is passed lightly over a limited skin area, with the interrupter vibrating rapidly, and when at the same time the secondary coil is moved slowly up towards the primary, a point is reached (threshold of stimulation), at which the patient begins to experience a slight *tickling* sensation. This is the *farado-cutaneous sensation.* With an increase in the strength of the current, this becomes a tingling sensation, which is at first disagreeable, and gradually becomes definitely *painful.*

The first sensation of tickling and the sensation of definite pain do not, in healthy subjects and for any given region, correspond to a fixed and invariable intensity of current, but usually approximate to an average obtained with a given position of the coils in each faradic apparatus. By noting on the one hand the threshold of farado-cutaneous sensation, and on the other the threshold of painful sensation, two figures are obtained between which is included what is known as the *faradic interval.*

The intensities required are practically equal for corresponding points on opposite sides, but vary with different regions of the skin surface. The sensation produced by a given current in the tips of the fingers, for instance, is well marked, whereas on the outer aspect of the thigh the same current will be scarcely perceptible.

To avoid all possible error due to suggestion, it is essential, in testing to determine the threshold, to

repeat the tests several times, and only to accept numerical results (measured in cms. of distance between the coils) which approximately agree.

Faradic Testing in Disorders of Sensibility. — Investigations of *the variations in sensibility in pathological conditions* (Drossdorf, Erb, Boudet de Pâris, etc.) have been directed to estimating, first, the threshold of farado-cutaneous sensation; secondly, the threshold of painful sensation; and lastly, variations of the faradic interval.

Pathological alterations of sensibility to the faradic current occur in organic disease and functional disorders, accompanied usually by sensory changes (neuroses, certain cerebral and spinal affections, tabes, section of the cord, certain forms of neuritis, etc.).

It was natural to suppose that the two stages in faradic sensation, farado-cutaneous sensation and painful sensation, corresponded to two forms of sensibility, sensibility to touch and sensibility to pain, and it was hoped that the intensity of the threshold stimulus would afford an objective measure of *quantitative pathological changes* in these two forms of sensibility. Actually, however, this is not so; as a general rule, the electrical sensibility of the skin varies in the same way as the sensibility to pain.

It is true that there are some exceptions to this rule. In tabes, for instance, as was shown by Erb, farado-cutaneous sensation may be normal, while the sensation of pain cannot be produced even with a current

of maximum strength. In this case, the "faradic interval" is equal to infinity ($I = \infty$).

According to Huet, similar changes may be met with in syringomyelia. They also occur in Brown-Séquard's paralysis. Except in these particular cases, variations in the sensibility to pain can be determined more accurately by means of the faradic current than by the usual clinical methods.

Determination of the exact limits of the area affected, objective measurement of changes in sensibility by a more delicate method than that of the needle, and study of the development of a sensory disorder by definite measurements, represent the advantages to the physician of testing sensibility electrically. It is worthy of remark that larger areas of altered sensation will often be detected by this procedure than by other means of investigation.

Hysterical anæsthesia, in addition to its segmental distribution, which can readily be verified by the faradic current, is also characteristic in being only partial. A current of a certain strength will always, in fact, give rise to sensation. This is the basis of the method of psychotherapy, which is now generally recognised as the most effective treatment.

Severance of a nerve should, in theory, produce total faradic anæsthesia, but in general it is only partial unless more than one nerve has been divided; in other words, it is important to take connecting and recurrent branches into consideration.

Testing sensibility may be of great value in the

clinical and topographical diagnosis of grave lesions of the cord. As in the case of a divided nerve, faradic testing will indicate the exact point at which the sensory path is interrupted.

In hemiplegia with crossed hemianæsthesia (Brown-Séquard's paralysis), faradic testing will show hyperalgesia on the side of the lesion, and on the opposite side an increase in the faradic interval, constituted by a greatly raised threshold of painful sensation (marked hypoalgesia) and a normal or slightly raised threshold of farado-cutaneous sensibility.

The Galvano-psychical Reflex.—With a very sensitive galvanometer, measuring extremely weak currents and graduated in micro-amperes, it is possible to determine whether certain disorders of sensation and the special senses are functional or organic, through the medium of the galvano-psychical reflex.

Discovered by Féré, and taken up later by Veraguth, this phenomenon has recently been studied in the course of military experience by one of the writers in collaboration with Logre.[1]

If a healthy subject be placed in a galvanic circuit of very low electromotive force (4 to 6 volts), the electrodes, which should be of metal and of considerable surface area, being kept closely in contact with the palms of the hands, any emotion or stimulation of any sensory nerve produces an instantaneous deflection of the galvanometer, indicating a sudden

[1] Zimmern and Logre, *Soc. de Neur.*, June and July 1917.

reduction of resistance at the points of contact with the body.

Any emotions, surprise, attention, or mental processes may give the reflex ; for this reason psychiaters have attempted utilising it as a measure of affectivity.

Sensory stimuli (touch, pricking, and heat), visual stimuli (a magnesium flash, for instance), and auditory stimuli (the ringing of a bell or vibration of a telephone transmitter), will also give rise to the phenomenon. Of the three forms of sensory stimulation, heat seems to be the most reliable and effective, in the sense that it always causes more galvanometric deflection than either of the others.

Certain authors have affirmed that these sensory stimuli do not act directly, but indirectly through an affective element (emotion resulting from perception), which would necessarily imply a psychical connecting link in the galvano-psychical reflex. It appears to us, however, that this affective stage in the reflex path is not essential to the production of the phenomenon, since in the case of hysterical subjects, in whom the reaction is usually pronounced, it would imply subconscious or conscious perception.

In extensive and profound organic anæsthesiæ (division of large nerve trunks without recurrent sensibility, division of the spinal cord, and tabes), if stimulation is carried out unobserved by the patient, to obviate the effects of expectant anticipation, no deflection of the galvanometer will follow. On the other hand, stimulation in a healthy region for pur-

poses of control will produce deflection. In hysteria, the amount of deflection is usually greater than in a healthy subject, and if the sensory disturbance is unilateral, the affected side will give a more pronounced response.

The same applies to the deaf: psychical deafness, or deafness which is largely functional, will always give a more or less marked deflection. In a case where the cause of deafness is organic, and hearing

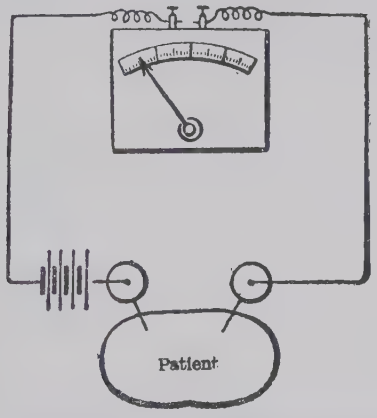


FIG. 42.—Apparatus for the galvano-psychic reflex.

has really been lost, a loud stimulus has no effect, whereas a thermal stimulus applied to the skin of the patient will cause a deflection.

It follows from these observations that the presence or exaggeration of the reflex will in some cases lead to suspicion, and in others prove that the sensory affection concerned is of a functional nature. Absence of the reflex, when satisfactory control tests have been performed in unaffected regions, is absolute proof of an organic lesion and of the genuineness of the case.

The physiological cause of the phenomenon is the sudden expulsion of sweat retained in the bodies of the sweat glands, by contraction of the unstriped muscle surrounding the epithelium of the lumen. The descending path of the reflex is through the sympathetic nerves, which control this momentary excretion. The reflex will obviously not be obtained if the sweat glands are not secreting, or secreting insufficiently, and it will be evident from the circumstances of its causation, that the expulsion of sweat will not continue indefinitely.

II. Affections of the Special Senses

Electrical Reactions of the Auditory Nerve. — The auditory is the only nerve of special sense the testing of which is of any clinical value. We shall merely summarise from Roques's [1] account, the results which may be obtained.

If the active electrode is placed in the external meatus of the ear to be tested, and the passive electrode some distance away, it will be found that the strength of the current can be increased to more than 10 milliamperes without producing a marked auditory sensation at kathodal closing. This sensation is only given with higher intensities. No sensation is given by a current of less than 10 milliamperes except in cases of auditory hyper-excitability.

The auditory reaction is not infrequently produced in the opposite ear. This phenomenon is known as

[1] Roques, *Arch. d'électr. méd.*, 1911.

the *paradoxical reaction*, and indicates that the ear detecting the sound is the affected ear in the case of a unilateral lesion, and the more seriously affected in a bilateral lesion. This hyper-excitability is met with in otitis media and interna, in hyperæmic affections of the labyrinth, and in all conditions which increase intra-cranial pressure (cerebal tumours, meningitis, etc.). On the other hand, absence of reaction to 20 milliamperes indicates grave changes in the two labyrinths.

CHAPTER V

VOLTAIC VERTIGO

THE infinite variety of head wounds, and the large percentage of cases involving ear trouble, deafness, and vertigo from fracture or concussion, have led to a study of voltaic vertigo in relation to these different conditions. It was shown by the work of Babinski and his pupils that of all the methods of testing the condition of the internal ear, voltaic vertigo is one of the most sensitive.

This at least is the view of the majority of otologists and neurologists, although some consider the modus operandi of the phenomenon too obscure, and regard other tests, rotatory, caloric, and galvanic nystagmus, as adequate for diagnostic purposes.

Galvanic Nystagmus.—When the ear is stimulated by passing a current of increasing strength between one tragus and the other, a slow simultaneous movement of both eyes towards the positive pole occurs when the strength of the current reaches 2 or 3 milliamperes ; this is followed by small and rapid movements in the opposite direction, *i.e. towards the negative* pole, constituting *fine rotatory nystagmus*. To observe this movement, the patient should be told to look down-

wards, and the operator should watch closely either the pupil or a vessel in the conjunctiva.

In place of the bipolar method, in which a current is passed from one tragus to the other, the unipolar method may be employed, which consists in applying an indifferent electrode to the back of the neck and the negative electrode to the ear which is being tested.

FIG. 43.—Galvanic nystagmus.

A relatively strong current (10 to 20 milliamperes) is required for producing nystagmus by this method, and the vertigo which this will produce renders the procedure decidedly unpleasant for the patient.

Whatever method is used, the movement in the nystagmus is always towards the negative pole in the normal condition.

When nystagmus is produced by a current of less than 2 ma., it may be regarded as indicating a change in the internal ear. This hyper-excitability is the rule in labyrinthine hæmorrhage (Ménière's syndrome), in

suppuration in the internal ear, and sometimes in sclerosis. When a current of more than 4 ma. is required; or if nystagmus is not produced by any current which can be tolerated (the limit being about 15 ma.), this hypo-excitability or inexcitability of the ear concerned is generally regarded as indicating grave changes in the posterior labyrinth (partial or total destruction, neuritis of the auditory nerve, etc.).

We are not aware that qualitative changes, as, for instance, abnormal direction of the movements of nystagmus, have ever been described. We have seen, however, a case of gunshot wound of the head, which was trephined, in which nystagmus was replaced by a remarkable movement of convergence.[1]

Normal Voltaic Vertigo. — Voltaic nystagmus is merely an element in the syndrome of voltaic vertigo; in itself it has only a relative diagnostic value, and it may even be absent in the normal state.

In a healthy subject, when two testing electrodes are applied immediately in front of the ear and a current of gradually increasing strength is passed, a series of *subjective* and *objective* phenomena is produced. With 1 to 2 ma., the patient first experiences a sensation of giddiness; with from 2 to 5 ma., other subjective phenomena appear—a metallic taste, phosphenes, ear-noises, marked vertigo, malaise, and nausea. At the same time objective phenomena occur, viz. nystagmus and *inclination of the head towards*

[1] A. Zimmern, *Soc. neurol.*, April 1917.

the positive pole, sometimes so pronounced that the patient may fall backwards. A current of 1 to 2 ma. will usually cause this movement; 5 ma. will always produce it in a normal person. But with a current of

FIG. 44.—Normal voltaic vertigo. The patient is leaning towards the + pole.

slowly increasing strength, the resulting slow and gradual movement may escape observation; in such a case, if the circuit is broken, a sudden further inclination of the head will usually occur, followed by return to the erect position.

When the electrodes are applied asymmetrically and at different levels—if, for instance, the positive electrode is placed above the usual point and the negative below it, below the lobe of the ear and behind the mandible—the movement produced is a *rotation* of the head on its vertical axis, towards the positive pole.

In young subjects the sensation of giddiness is particularly marked, and quite a weak current (1 to 2 ma.) is sufficient to produce it.

Erb, in experiments on himself, made the following observations: One side of the body seems to have lost its weight, with the result that the body falls on the opposite side; the subjective sensation of unsteadiness is greater than the actual movement produced; if the eyes are closed, the body seems to have moved farther than is actually the case.

According to Escat, the objective reaction, that is to say, the lateral inclination, is much more evident if the subject is standing with the heels together and the eyes closed, *i.e.* in the attitude assumed for obtaining Rhomberg's sign (fig. 44). In this position there is not only a movement of the head, but an inclination of the whole body towards the positive pole.[1]

Otologists frequently employ the unipolar method, placing the positive electrode on the back of the neck and the negative over the ear, as was described in

[1] The various vestibular tests produce reactional movements which may spread to all parts of the body simultaneously. Each reactional movement is followed by a counter-reactional movement in opposite direction. In voltaic vertigo, the reaction is easily produced, and the counter-reaction is immediate (Babinski).

connection with nystagmus; with this arrangement a stronger current is required for producing vertigo, and its effects are sometimes less easily tolerated than if the bipolar method is employed.

It is essential in carrying out these tests to repeat them a number of times in succession, when the reaction being constant, the conclusion will be beyond doubt. At the same time care should be taken not to repeat the stimulus at very short intervals, since the effect of the current diminishes, and movement is therefore no longer produced.

Voltaic Angular Deviation.—If a healthy individual be asked to close his eyes after making a note of a certain direction, and then to take six steps forward in this direction, followed by six steps back in the opposite direction, it will be found that he does not deviate appreciably from his original line of direction. This is the test of spontaneous angular deviation suggested by Babinski and G. A. Weill.[1]

In a subject whose mechanism of equilibrium is affected, the deviation is such that if he is stopped after several turns backwards and forwards, he will find himself facing in an opposite direction from that in which he started, or at least considerably to the right or left of it.

If this walking test be applied to a healthy subject simultaneously with Barany's thermal test, deviation occurs in a direction opposite to that of the nystagmus

[1] Babinski and G. A. Weill, *Soc. biol.*, April 26th, 1913.

produced (Buys). With cold water, there is deviation towards the side of the ear in which it has been applied.

More accurate results are obtained with bitemporal electrical stimulation during the walking test, the electrodes being kept in position over the tragus by elastic bands, and connected by wandering leads to the galvanic apparatus. In a normal individual, a current of 1 to 1½ ma. causes inclination towards the side of the anode; the direction taken alters towards the positive pole, a deviation of 10° to 15° being produced in each forward or backward course. Consequently, when the ground has been covered forwards and backwards four times the total deviation will be 190°. This is voltaic angular deviation.[1] The actual course pursued assumes the form of a star.[2]

If the test be repeated immediately after breaking the circuit, deviation towards the opposite side is produced; this is known as voltaic counter-deviation.

With a current of more than 2 ma., the shoulder falls towards the positive pole, the gait is asymmetrical, and phenomena of interference with equilibrium may even appear as drunken, staggering gait and reflex movements aimed at restoring equilibrum (Cestan).

The Normal Vestibular Reactions.—In brief, the following reactions are given by healthy individuals with no lesion of the ear:

1. Nystagmus, the movement being towards the negative pole.

[1] Babinski and G. A. Weill, *Soc. biol.*, July 19th, 1913.

[2] Cestan, Descomps, and Sauvage, *Soc. Méd. des Hop.*, May 1916.

2. Inclination towards the positive pole, whatever its position, whether over one ear or the other, with a current of 2 to 5 ma.

3. Voltaic angular deviation towards the positive pole.

These normal reactions are given, not only by healthy individuals, but by individuals suffering from *psychical deafness.* But a deaf person with normal reactions should not be regarded on this account as suffering from functional deafness or as a malingerer. Only anomalous reactions possess a definite diagnostic significance.

It is generally recognised that abnormalities of voltaic vertigo are the result of *vestibular lesions* ; deafness from an organic cause will therefore be unaccompanied by abnormal vertigo unless the lesion spreads to the vestibule.

Abnormal Vestibular Reactions.—Although the relation between modifications of voltaic vertigo in the pathological state, and the pathological changes concerned is still imperfectly understood, clinical experience has firmly established the following conclusions :

Two kinds of modification must be considered—quantitative changes in the strength of current required for producing inclination, and changes in the direction of the inclination.

(*a*) *Quantitative Modifications :*

There is said to be *hyper-excitability* when an ex-

tremely disagreeable sensation of vertigo is rapidly produced, and continues after stimulation ceases; when inclination is caused by a current of 1 to 3 ma.; or again, when the extent of the movement is exaggerated. In certain cases, very weak currents are liable to produce an unsteadiness of the head, which moves in all directions—forwards, backwards, and laterally; this condition has been called cephalic nystagmus.

This hyper-excitability occurs in acute or chronic suppurative otitis, more particularly during the development of acute labyrinthitis (Hautant).

Hypo-excitability, sometimes known as *resistance to vertigo*, is characterised by the fact that the subjective sensation of vertigo can only be produced with difficulty, and that 10 to 15 ma. are required for producing inclination.

Hypo-excitability may be unilateral, inclination on one side being produced by a current of 2 to 5 ma., and on the other only by 10 ma. or more.

In these cases of hypo-excitability, rotation, angular deviation, and nystagmus are equally affected, all three requiring abnormally strong currents. Nystagmus may even be absent.

When the objective reactions of vertigo are entirely absent, there is said to be *inexcitability* or *absolute resistance* to vertigo.

Hypo-excitability occurs in chronic changes in the labyrinth (grave suppurative labyrinthitis), in chronic otitis media with involvement of the labyrinth, in

sclerosis of the internal ear, and lastly in head injuries (fracture, concussion, etc.). It is usually present in intracranial lesions which cause an increase in the pressure of the cerebro-spinal fluid.

Inexcitability would appear to indicate destructive changes in both labyrinths, or at least a very serious bilateral lesion (fractures of the base).

(*b*) *Changes in Direction of the Inclination*:

Anomalies in the direction of the inclination usually coexist with one of the foregoing quantitative changes. Hyper-excitability or hypo-excitability, however, do not necessarily imply such an anomaly: the inclination may be normal in direction, even in severe labyrinthine lesions. Hautant found no changes in the direction of the inclination in cases of suppurative labyrinthitis, or after trephining to expose the labyrinth.

Anomalies of inclination are of three types:

1. There may be simply *predominance of amplitude*. The positive pole still determines the direction of the inclination, but the extent of the movement is always greater on one side; this indicates a change in the ear of that side if the affection is unilateral, or a severer lesion on that side if the affection is bilateral.

2. The inclination is *invariably towards the same side*. Whatever the position of the positive pole, the head inclines towards the side on which the labyrinth is affected, or affected in greater degree, according to the formula stated by Babinski in 1903.

This rule is not, however, invariable. There may

be inclination only towards the unaffected side, as in complete unilateral destruction of the vestibular mechanism; or there may be inclination towards the affected side when the positive pole is applied to that side, and a rapid backward movement when it is applied to the unaffected side.

3. In some cases inclination is *absolutely irregular*, sometimes to one side, sometimes to the other; in other cases the movement is always backward. These phenomena are often accompanied by great diminution in excitability, and appear to indicate bilateral lesions.

The Vestibular Reactions in Head Injuries, Concussion, and After Trephining.—A. *Voltaic Vertigo.*—Testing voltaic vertigo in cases of head injury has shown that the reactions are commonly abnormal.

It is not essential that the petrous portion of the temporal bone should be involved: abnormalities of vertigo may follow fracture of any part of the skull, or even simple concussion.

Injuries of the skull often leave the patient with sensations of giddiness of various kinds, disorders of equilibrium, and disorders of hearing. These are usually accompanied by changes in the objective reactions, consisting of modifications of excitability, diminished or absent nystagmus, and abnormal direction of inclination. It is not exceptional to find profound changes in voltaic vertigo where the clinical manifestations are slight (slight vertigo, and reduced acuteness of hearing).

These changes indicate that the subjective symptoms are of organic origin, and dispose of the idea that the disorder is psychical or simulated (Babinski).

Cestan regarded quantitative changes as an almost invariable feature in head injuries. Hypo-excitability is present in cases where trephining has been performed or a certain amount of bone has been removed, and hyper-excitability in concussion and injuries of the mastoid and occipital.

A number of different changes in the direction of the inclination would appear to be possible, since in cases which Babinski studied after trephining, the normal inclination and rotation were replaced either by unilateral inclination, unilateral rotation, inclination and rotation on one side only, inclination on one side and rotation on the other, circumduction of the head, forward and backward movements of the head, or, lastly, by cephalic nystagmus.

B. *Voltaic Angular Deviation.*—The effect of the galvanic current on forward movement has been studied notably by Cestan, Descomps, Euzière, and Sauvage,[1] who observed changes in the type, direction, and degree of angular deviation.

In place of the star-shaped line of movement, which they regarded as normal, they frequently observed a lateral deviation (curve or zig-zag) with one or both positions of the positive pole.

As with the inclination in vertigo, there may be

[1] Cestan, Descomps, Euzière, and Sauvage, *Soc. Méd. Hop.*, October 27th, 1916.

univocal angular deviation independent of the position of the positive pole.

Lastly, whereas the angle of deviation in a healthy individual is about 90°, this may be increased or reduced in pathological conditions, and is sometimes even greater in one direction than in the other. Equal extent of deviation in both stages of the test (deviation and counter-deviation) is exceptional in disease.

The diagnostic value of these changes is similar to that of abnormal voltaic vertigo. Cestan further asserts that whenever vertigo is abnormal, the deviation produced by an electric current will indicate similar conclusions. It must not be assumed, however, that the results of these two tests will always be analogous in form; to give only a single example, bilateral inclination in vertigo may be accompanied by unilateral angular deviation. These facts do not militate against the value of the method when it is applied, not for the purpose of discovering the exact situation or nature of the lesion, but in order to prove that the subjective symptoms of which the patient complains have some basis in actual organic change.

The Theory of Anomalies in Voltaic Vertigo.—*Nystagmus* is produced by stimulation (rotation, heating, or galvanisation) of one of the vestibules, the vestibular nerve, or of its nuclei in the medulla.

In the vestibule, the reflex appears to originate more particularly in the ampullary region of the semicircular canals. The hair-cells of the crista acustica are affected by movements of the endolymph, and transmit this stimulus to the terminations of the vestibular nerve.

Barany's caloric nystagmus is usually regarded as being produced by an ascending current in the endolymph, its temperature in the

external semicircular canal being raised; this effect has even been regarded as explaining galvanic nystagmus in cataphoresis and galvanotropism of the hair-cells (Brunings).

It is difficult, however, to believe that in caloric nystagmus the liquid injected into the external ear will raise the temperature of the internal ear sufficiently to produce convection currents. Further, such currents would hardly affect the walls of the canals, and consequently the hair-cells; in a capillary tube about the size of a pin (*i.e.* of the same diameter as the semicircular canals), filled with liquid of a certain viscosity, movement is almost entirely confined to the centre of the column, and the liquid in contact with the walls of the tube is almost stationary.

The possibility of electrical convection seems equally unlikely, in view of the minute size of the semicircular canals, and consequently the insignificant fraction of the current which traverses them.

On the contrary, it seems much more reasonable to suggest that here, as elsewhere, the galvanic current acts directly by stimulating the vestibular nerve. It has been shown that galvanic nystagmus not only occurs in lesions of the labyrinth, but also in cases in which the nerve endings are affected.

Voltaic vertigo, properly so-called, also originates in stimulation of the posterior labyrinth.

Babinski's experiments on the pigeon, and those of Weill, Barré, and Vincent on the guinea-pig, leave no possibility of doubt on this point. Experimental galvanic stimulation of the labyrinth in the animal produces the phenomena of voltaic vertigo, and destruction of the labyrinth abolishes them.

In the guinea-pig, the rotation normally produced by the action of the positive pole is generally absent after unilateral extirpation of the labyrinth. It can only be produced by applying the positive pole on the opposite side. After bilateral extirpation no movement can be produced.

Extracranial section of the auditory nerve gives similar results. It is therefore evident that the vertigo is not a purely labyrinthine effect, but depends on stimulation of the centripetal fibres (vestibular nerve) originating in the labyrinth.

The mechanism of the reflex itself, the muscles concerned in the movements produced, the relation of these movements to labyrinthine tonus, and the specific action of the positive pole, represent questions of which, as yet, we know very little.

CHAPTER VI

Electro-Diagnosis and the Medical Boards

The importance of electrical diagnosis has been recognised by the army medical service, with the result that the report on an electrical examination has been given adequate prominence in Medical Board papers.

Every case of paralysis of any kind or degree should be sent for electrical examination.

When it is remembered that the Medical Board, the Minister, or even Council of State which represents the final court of appeal in awarding pensions, have only medical reports from which to draw their conclusions, it will be recognised that these reports should include, whenever possible, unquestionable scientific data, which will verify the clinical evidence and assist the decisions of experts.

Camus has shown how much can be gained from physiological means of examination (the dynamo-ergograph and measurement of the vaso-motor and psycho-motor reactions): of these procedures, electrical examination is second to none in importance.

There will be no question of a paralysis when a recent electrical examination confirms its existence.

Further, although a clinical examination will determine the extent of functional impairment, the electrical reactions will often indicate the prognosis, an important factor in estimating the extent of a disability, and particularly in deciding whether a man is to be discharged from the army, discharged temporarily, or transferred to an auxiliary branch.

It was hoped by some that electrical methods would afford objective evidence of the functional power of nerves and muscles, and that the formulæ—complete RD, partial RD, etc.—would be of value as indicating definite degrees of disability. Attempts have also been made to class the various stages of RD in degrees, according to the state of faradic and galvanic excitability, the polar formula, the nature of the contraction, and the longitudinal reaction, each of these signs to indicate a further stage in degeneration. Such a classification as this would obviously provide a scale of degrees of severity which would enable any medical officer, apart from special qualifications, to form conclusions with a minimum of difficulty. But this system is far from corresponding to clinical reality ; it may rightly be applied in cases of recent injury, but it is wide of the mark in long-standing paralyses, such as appear before Medical Boards. Such cases may have improved, or complete functional recovery may have taken place, but at the same time, as members of Medical Boards have very rightly been reminded by the *Guide-barème des Invalidités*, voluntary movement is recovered before regressive changes

in the electrical reactions have begun. The results of electrical examination may therefore be identical in two cases, in one of which function has to a great extent been recovered, while in the other nothing beyond muscular tone has been regained. If the electrical reactions were taken as sole guide, the extent of the disability would be assessed as equal in the two cases.

Larat has proposed simplifying the terminology by abolishing the expression "partial RD," a condition which he himself regards as indicating an early and rapid improvement. We are not of the opinion that the term should be abolished, since partial RD may occur, either as a preliminary stage to complete RD, or, on the other hand, during the regressive period, where it reflects the traces of the lesion that remain.

Actually, however, whatever term may be employed to describe a group of abnormal electrical reactions, it cannot adequately inform a Medical Board of the exact condition of affairs. It is only by interpreting the electrical reactions and correlating them with clinical observations that a conclusion can rightly be drawn.

What information can the Medical Board obtain from an electrical examination ?

The presence of abnormal electrical reactions differentiates at once between organic paralyses and simulated, hysterical, or functional paralyses (Babinski type). In the majority of cases, when the

case appears before the Medical Board, an electrical examination merely confirms the clinical diagnosis.[1] We have already mentioned that it is common for a functional paralysis to be associated with an organic lesion : in such cases, an electrical examination will differentiate between what is due to hysteria and what to organic change.

An electrical examination for the purposes of a Medical Board often reveals an unsuspected lesion. If, for instance, the Board is faced with an ankylosis of the knee following an arthrotomy for articular fracture, and this is found to be accompanied by interference with the movements of the foot, electrical examination will often reveal an unrecognised lesion of the external popliteal nerve, the foot-drop having previously been attributed to the prolonged immobilisation or to muscular atrophy. We have mentioned elsewhere that paralysis of the ulnar may pass unrecognised apart from an electrical examination. Similarly, in cases which have been in hospital for some months and are in process of being boarded out

[1] During the first two years of the war, we frequently found in the medical history sheets of cases sent to us for electrical examination, observations implying an organic lesion of a peripheral nerve, whereas the reactions were found to be absolutely normal. Proceeding with a clinical examination, we generally found that the case was one of functional paralysis. Duco and Blum describe numerous cases in which a further examination ordered by the Board led to alteration of the original diagnosis of an organic lesion. Some months ago, specialists for conducting neurological examinations were attached to all Medical Boards, in districts where there was no neurological centre. Unrecognised hysterical paralyses are now very rarely to be met.

of the army, we have frequently discovered grave nerve lesions with complete RD, which had previously been unsuspected; in some cases a bone lesion was the principal injury (in articular fracture of the wrist with ankylosis, for instance, paralysis of the muscles of the thenar eminence may remain unnoticed), in others, it may only have been observed that one nerve is paralysed, whereas another is equally affected. It seems hardly necessary to emphasise the importance, from the point of view of the man's own interests, of carrying out this additional examination.

In organic paralyses of peripheral nerves, an electrical examination will determine the actual condition of the lesion. It is not sufficient to carry out a rapid examination and then to say that RD is or is not present; it is also necessary to determine the stage of the degeneration and to interpret these data, to find whether the electrical reactions suggest a lesion capable of repair, or a permanent lesion, since the decision as to the degree of disability and future of the man concerned (discharge, temporary discharge, or transfer to an auxiliary branch), which depend on the results of this examination and on the clinical evidence, will be decidedly different in each case.

Hypo-excitability may be found to be the only anomaly in the electrical reactions; in some cases it is the only remaining trace of an RD in process of regression, in others it is entirely independent of RD.

It occurs in simple muscular atrophies, but also in certain nerve lesions, the clinical signs of which suggest a grave condition. Simple hypo-excitability is usually a favourable sign.

Partial RD also suggests a favourable prognosis in the majority of cases; it may be present either in slight paralyses or during nerve regeneration.

Complete RD indicates a grave nerve lesion. Its manner of evolution being variable, its significance in prognosis depends on whether that evolution appears to be progressive or regressive. The nerve, as well as the muscles, should be tested, since it is in the former that the first signs of regressive change appear. Longitudinal hyper-excitability is also an important sign, but is not in itself a sufficient reason for concluding that the paralysis is incurable: in toxic neuritis, for instance, longitudinal hyper-excitability is common, but recovery usually takes place. In the vast majority of cases, reliable conclusions can only be based on repeated examinations, or on sufficiently explicit reports of previous electrical examinations.

Absolute inexcitability must logically be regarded as indication that the lesion is incapable of repair. It is certainly an extremely grave sign, but it must be remembered that after suitable physiotherapeutic treatment, or an operation (suture or liberation of the nerve), inexcitability may persist for a long time before the appearance even of the earlier effects of successful treatment. It is therefore advisable in some cases to

postpone the decision when the condition is suspected of being incurable. When the lesion dates from more than a year previously, when muscular atrophy is marked, and accompanied by marked trophic disorder, it is almost impossible that function can even partially be recovered.

Compensation for injuries received, either on active or during home service, takes one of two forms, a pension or a gratuity. By the terms of the Act of 1831, which is still in force, a pension is only awarded when the disability is both severe and incurable. This is a pension for life, and even though it may have been granted owing to an error in diagnosis or prognosis, the State has no alternative, and it must continue to be paid; hence the importance of avoiding haste in deciding that a nerve lesion is incurable.

A gratuity is granted when the extent of functional impairment is at least 10 per cent.; the condition may be curable within a variable length of time, even such that recovery is comparatively rapid. According to the nature of the case, the man is either discharged permanently, in which case the gratuity awarded will be paid every two years, or he is discharged temporarily, which means that he may be called up again for active service twelve months later, for which period he receives the gratuity awarded. Thirdly, a man recommended for a gratuity may be transferred to auxiliary service if his disability is not so serious as to be incompatible with such service, in accordance

with the stated instructions as to physical fitness for military service.

The testing of voltaic vertigo, together with the examination of the cerebro-spinal fluid in cases of head injury (trephining or concussion), became compulsory, following a meeting of the Société de Neurologie in April 1916. This was a fortunate decision. since abnormal vertigo demonstrates the objective nature of the disorders (vertigo and headache) of which the patient complains. Abnormalities in vertigo should be taken into account in the decisions of a Medical Board, but, as with the muscular reactions, they can only be a single factor in that decision. Lortat-Jacob requested that no head case with abnormal vertigo should return to active service ; Laignel-Lavastine will never send a man back to his depôt until his vertigo is normal. As a matter of fact, it is impossible to state a definite rule.

In short, although electro-diagnosis cannot determine the precise nature of a nerve lesion, it is of great value to the Medical Board as an objective sign of an organic lesion and as a factor in deciding the prognosis. It is therefore absolutely essential that the examination should be exactly and carefully carried out.

In every case a report should be written, dealing not merely with the elementary reactions obtained, but giving clear and concise conclusions. We have already pointed out the faults of arbitrary classifica-

tions ; nothing so clearly illustrates the ever-recurring difficulty in forming conclusions as the apparent discrepancies by which we are sometimes momentarily nonplussed. The decision of the electrologist is a matter of judgment, for all cases have their individual character.

DOCUMENTS

I

39 C 1/7. *March 15th*, 1916.

Organisation of medico-legal procedure in cases recommended for pensions and permanent discharge

You are instructed to draw up what is known as the *Dossier médical* of the man in question; that is to say, the combined reports which will enable specialists such as the members of the consulting commission to ascertain the cause, the exact nature, the origin, the degree of gravity, and the condition of incurability or non-incurability of diseases and disabilities.

This medico-legal dossier contains the reports of duly qualified specialists (ophthalmologists, oto-rhinologists, neurologists, etc.), the results of electrical examinations, radiographic examinations, etc.; in fact, all data essential for judging of the gravity and the incurability or non-incurability of the disabilities concerned.

II

GUIDE-BARÈME DES INVALIDITÉS, 1915

Paralysis of Nerves

Every case of paralysis involves a study of the impairment of movement and sensation, the condition of the reflexes, and vaso-motor, trophic, and electrical disorders.

The latter in particular are of the greatest importance, from the point of view both of the gravity of the lesion and of the prognosis, and consequently of estimating the degree of disability.

It is of particular importance to determine whether RD is present. Its presence definitely indicates a lesion of the peripheral motor neurone.

RD may be complete or partial.

Complete RD appears in cases of complete division of the nerve, and in many cases of compression. It corresponds to *complete paralysis.*

Partial RD occurs in compression and irritation of the peripheral motor neurone. It corresponds to *incomplete paralysis.*

When complete RD is observed, the condition is *grave*, and *often incurable.*

It should not be concluded prematurely, however, that the paralysis is incurable: this conclusion is only permissible when prolonged and vigorous treatment has been without effect.

Nerves, like all other tissues, when they have been injured, have a natural tendency to undergo repair, and in this process the axis-cylinder is the first element to regenerate. Now this axis-cylinder is capable of transmitting an electrical stimulus, and in accordance with the law stated by Duchenne (of Boulogne), the power of voluntary movement reappears earlier than electrical excitability.

If, on the other hand, the lesion is in process of becoming incurable, the nerve remains permanently inexcitable, and in the case of the muscle, hypo-excitability is succeeded by inexcitability.

If RD is partial, the prognosis is more favourable; the condition is curable, and if recovery is not certain, it is at least extremely probable.

III

348 C 1/7 CCM. *December 5th*, 1916.

Medical examination of cases of head wounds from the point of view of fitness for further service

Le Sous-Secrétaire d'Etat du Service de Santé militaire to MM. les Directeurs du Service de Santés des Régions.

The question of the fitness for service of men who have received head wounds has been the subject of numerous discussions. At the meeting of members of the Société de Neurologie de Paris and representatives from military neurological centres, the problem was examined, and it was decided that from facts hitherto observed and interpreted the following conclusions could be drawn.

In the first place, head injuries involving grave organic lesions of the nervous system, such as hemiplegia, monoplegia, loss of speech, very extensive losses of bone, etc., obviously incompatible with any form of military service, must be excluded.

Apart from these cases, it is necessary in every case of head injury to examine for a number of other disorders, the presence of which is important from the point of view of the prognosis : headache, phosphenes, dizziness ; labyrinthine, visual, and mental disorders ; abnormalities in voltaic vertigo ; the emotional, sympathetic, circulatory, and secretory reactions ; and lastly, excess of albumen in the cerebro-spinal fluid, etc.

As regards the course to be adopted in cases in which these disorders have been present, or are still present, it appears difficult and undesirable to formulate arbitrary instructions ; account should always be taken of the individual nature of the case.

It may, however, be stated as a principle that men

who have received head wounds should not return to the front, apart from altogether exceptional cases which have been submitted to prolonged observation.

The procedure indicated is usually temporary discharge, or transfer to an auxiliary branch of the service.

JUSTIN GODART.

SECTION II

DISABILITIES OF THE LOCOMOTOR APPARATUS FROM WOUNDS

DISABILITIES OF THE LOCOMOTOR APPARATUS FROM WOUNDS

PART I

ARTICULAR LESIONS: ANKYLOSIS

A JOINT may become affected as regards the stability, the strength, and the range of its movements by lesions that involve

1. the joint itself—its bony or ligamentous elements ;

2. the surrounding soft parts, which include :

(*a*) The skin and subcutaneous connective tissue, cicatricial retraction of which often succeeds in putting a definite obstacle in the way of joint movement in one or more directions.

(*b*) The muscles, which, with their tendons, become atrophied, fibrotic and retracted, shortened, adherent or paralysed.

3. The shafts of neighbouring bones which, after fracture, have either united in mal-position or else failed to unite altogether.

Such lesions end in a great variety of mechanical disabilities—unstable or flail joints, muscular weakness or absolute loss of power, deformities and attitudes that in themselves are disabilities, ankylosis and stiffness of joints! To give a description of all the possible combinations of these conditions would be quite impossible, so great is their variety,

owing to the nature and complexity of the initial destruction of tissue, and on the severity and character of the infective complications. There exist, however, certain clinical types which will be studied in this book in the order already laid down.

In addition, in the most complex cases, an accurate comprehension of the exact nature of the original lesion is an indispensable condition for adequate and rational treatment, and for determining which cases are amenable to physiotherapy, and which require operative surgical interference. The classification of cases into these two classes—those in which physiotherapeutic and those in which operative measures are indicated—has not up to the present always been carried out with sufficient accuracy, so that it is not at all rare to meet with cases that have stagnated for long periods in physiotherapeutic centres, receiving treatment that is useless or inadequate; either hopelessly inadequate, as in persistent attempts to mobilise a joint the seat of complete ankylosis, whether bony or firm fibrous; or useless, as when progress beyond a certain point becomes impossible because of the existence of a mechanical obstacle that can be overcome only by its surgical removal. There is another class of case which I need not at present do more than refer to, but in which treatment by such physiotherapeutic methods is absolutely harmful and pernicious.

On the other hand, it is not always easy to determine at what moment or by what method an operation should be performed, nor can its probable degree of success be foretold with anything like absolute certainty. The surgeon may be convinced of the existence of a definite mechanical obstacle to movement,

but, uncertain of the possible co-existence of other lesions, he cannot be sure that its removal alone will result in restoration of the desired range of movement.

Let no one expect, then, to find in this book any absolute data concerning pathological anatomy, classification, or operative technique, but merely certain constant fundamental principles in connection with the best methods for the reduction of disability.

THE VARIETIES OF ANKYLOSIS

All lesions that end either in limitation or in complete suppression of the normal range of movement of a joint are usually included in the one general term of ankylosis.

To be correctly used, however, this term should be held strictly to imply the complete cessation or disappearance of the initial causative pathological process in the joint. Now, very often the full significance of this element in ankylosis is not grasped. How often, for instance, does one hear described as ankylosis the limitation of joint movement that characterises the earlier stages of a tuberculous arthritis ? By constituting a serious error in nomenclature this often leads to a consequent grave mistake in treatment ; for so long as inflammation, whatever its origin and nature, is still present in a joint, it is that inflammation against which all treatment should be concentrated ; and such treatment is in most cases, if not in all, the exact opposite of that indicated in the condition of ankylosis of the joint in which the inflammation has finally subsided.

Ankylosis, thus defined, includes a great variety of conditions that it is very difficult if not impossible to classify with any exactness in definite water-tight compartments.

According to the pathogeny and the nature of the lesions concerned and the degree of the functional disability that results from them, we can and should distinguish, however, between the following varieties of ankylosis :

Intra- and Extra-articular Ankylosis,
Fibrous and Bony Ankylosis,
Complete and Incomplete Ankylosis.

But these different categories overlap ; for example, fibrous intra-articular ankylosis is often practically a complete ankylosis, falls in effect into the same clinical category as complete bony anyklosis ; certain cases of extra-articular ankylosis will prove to be bony and complete ; others of incomplete bony ankylosis will be found to result from overgrowth or deformity of the articular ends of the bone ; certain cases of manifestly intra-articular origin will be clinically cases of mere stiffness of peri-articular origin.

In practice, however, and as far as surgical indications are concerned, two principal forms of ankylosis are to be recognised :

1. True ankylosis, most often of intra-articular origin, in which all attempts at treatment by non-surgical means are doomed to failure.

2. Joint stiffness or false ankylosis, in which, on the other hand, mobility is to be restored in the first place by physiotherapeutic methods, assisted in different cases to a greater or less degree by occasional surgical intervention.

In cases of complete ankylosis the position of fixation of the joint is of capital importance ; in cases of incomplete ankylosis and of mere joint

stiffness,—the direction and the range of the movement that remains. These determine to a great extent the future utility of the limb. I will discuss these points in connection with true ankylosis in the case of each of the individual joints.

CHAPTER I

TRUE AND COMPLETE ANKYLOSIS

1. General Considerations

Nomenclature.—True ankylosis is that in which all movement, active and passive alike, is suppressed, and in which a restoration of mobility cannot be effected except by the performance of a definite surgical operation—that of joint resection ; of the indications for this operation as of those for the correction of a concomitant mal-position a careful consideration is necessary.

Almost always such ankylosis is of an arthritic, of a definitely inflammatory origin ; in war surgery it usually follows a suppurative arthritis that has been complicated and accompanied by a more or less chronic inflammation of the neighbouring articular bone. Such a process almost inevitably ends sooner or later in bony ankylosis ; sometimes, however, in very firm fibrous intra-articular ankylosis—a condition to all practical intents and purposes identical with that of actual synostosis.

In the same practical class with these forms of intra-articular ankylosis is to be placed that variety of ankylosis in which are formed peri-articular bridges of bony outgrowths that arise by ossification of the

muscles and tendons. In such also it will at once be evident that the operative removal of these exostoses offers the only chance either of correction of the fixed mal-position or of the successful mobilisation of the joint.

Because of a tendency to recurrence after removal of these exostoses the treatment of this condition, *ankylose cerclée*,—a variety of ankylosis that most commonly affects the elbow joint—often presents considerable difficulties. I have never met with this condition in war wounds, but both in order to avoid the necessity for referring to it later on, and because its study leads to important practical considerations, I will devote a little space to it here.

As a matter of fact it is one of the possible consequences of backward dislocation of the elbow joint in young people, and indeed, in my experience, the younger the patient the more marked the condition. In the first place, massage favours the formation of the osteophytes; secondly, where actual ossification of the periosteum and of the muscles has occurred, massage has the effect of stimulating and not of checking the process; in the third place, a too early removal of the bony outgrowths is very apt to be followed by their recurrence; only one operation should be performed, and that only when the new bone has become dense and compact. I will say no more about this condition, because I have met with no example of it at the Grand Palais, where, however, I have seen several cases of stiffness following dislocation of the shoulder, but none after dislocation of the elbow joint.

Certain cases of incomplete ankylosis, in which the range of movement is merely limited in one or more

directions, are to be regarded as cases of true ankylosis when the cause of such limitation is bony, either intra-articular (from inflammatory overgrowth of an infected articular epiphysis) or extra-articular (for example, the projection forwards of a buttress of the upper fragment of a supracondylar fracture of the humerus). In these cases, after care has been taken to ascertain the possible existence of any additional cause of stiffness of the joint, it will be necessary, according to the circumstances of the case, either to remove surgically such a bony obstacle or to leave it alone, and it is the duty of the clinical observer to consider and decide which of these alternatives should be adopted in individual cases.

In order to establish the existence and the nature of such obstacles to full joint movement as exist a radiographic plate should always be taken; merely screening the part does not allow of a sufficiently detailed examination.

In this way one is enabled to see whether or not the joint space between the articular surfaces is clear or opaque. Opacity indicates the existence of a synostosis. Two plates taken at right angles to each other will show whether such a synostosis is complete or partial, and, in the latter case, its exact position and extent. On the other hand, transparency of this joint line does not in a case of ankylosis necessarily mean that this is fibrous and not bony, since we know that newly-formed bone may remain for long permeable to the X-rays. The radiograms will also show quite clearly any peri-articular deposits or spurs of bone, any changes in the size and shape of the epiphyses, and also the existence and position of patches of inflammatory rarefaction.

Information gained thus by radiographic examination is not always absolutely definite and decisive, but it is very much more so than that gained by simple clinical testing of the existence—under an anæsthetic where necessary—of residual movement in the joint, or by noting, in an unanæsthetised patient, the presence and amount of the pain induced by attempting to mobilise the joint.

A combination of these methods is, however, useful in coming to a decision as to the indications for treatment that exist in individual cases.

Indications for Treatment.—In all cases of true ankylosis the important question to decide is whether operation is indicated or not. In coming to a decision on this point, whilst regarding the position of ankylosis as the most important factor, we have also to take into consideration the nature, the extent, and the seat of the pathological basis of the limitation of the joint movement. There will be, for instance, less hesitation in removing a mere bony outgrowth than in practising a free full resection of the affected joint.

The position of ankylosis will remain, however, by far the most important consideration. In the case of each joint there exist positions of ankylosis that interfere but little with the functional utility of the limb, others that seriously diminish, even in some cases almost completely abolish, such utility. These various positions will be discussed a few pages further on in connection with each of the individual joints.

Hence the indications for treatment may be summed up in the following manner :

1. In cases of ankylosis in good position we have to consider whether operation furnishes a fair chance of

restoring the mobility of the joint; where it does not, it is definitely contra-indicated.

2. In cases of ankylosis in mal-position the fundamental indication is the correction of the mal-position, its conversion into a position that is from the functional point of view more useful; the possibility of in addition restoring the joint mobility must be regarded as a secondary consideration.

Cases of incomplete ankylosis in which the range of movement that persists does not allow of the joint assuming its position of maximum utility are to be regarded as cases of ankylosis in mal-position; for example, incomplete ankylosis of the knee joint with extension limited to 135° and with a normal range of flexion carries with it the same mechanical consequences as would result from complete ankylosis of the joint at this angle of 135°. Again, an incomplete ankylosis of the knee joint in which full extension but only a few degrees of flexion is possible is from this point of view practically identical with complete ankylosis in full extension.

It is most necessary to adhere to a constant fixed system of expression of these measurements of joint angles; such is in practice very rarely carried out. Thus one very commonly hears such an expression as "ankylosis of the elbow joint at 135° of flexion," *i.e.* at an obtuse angle; what is really meant is ankylosis at 135° of extension; and when it is said that flexion of the elbow reaches 45°, what is meant is that 45° of flexion beyond the right angle is possible; in other words, that there is present 135° of flexion. For hinge joints, like the elbow and the knee, the only scientific method of estimating the degrees of flexion and extension consists in regarding the 0° of one

movement as the maximum of 180° of the movement in the opposite direction. An elbow in the straight or fully extended position of the arm should be regarded as possessing 0° of flexion or 180° of extension, and these two opposite movements should be estimated in correspondingly opposite directions. Thus 45° of flexion should be synonymous with 135° of extension. As regards the common expression "ankylosis of the knee or elbow in the semi-flexed position," this really implies that the vertical, fully extended position is taken as the point of departure, and the right angle as the point of arrival or termination of the movement, so that this expression is synonymous with 45° of flexion or with 135° of extension. In point of fact, it is the right-angled position that in the case of hinge joints should be regarded as the point of semi-flexion or of semi-extension.

In the case of joints where circumduction is possible, one should always take the vertical position of the particular bony lever that is regarded for the moment as the active moving one (the subject occupying the traditional anatomical position) as the point of departure, the 0° of the scale for all the movements. It is very often held that the hip joint is in the extended position when the thigh is vertical, and that any further movement backwards of the thigh constitutes hyperextension: this again is a further example of inaccurate terminology, for the vertical position should always be regarded as the point of departure, the 0° of the scale from which is to be estimated the number of degrees alike of flexion and extension as of abduction and adduction; in the case of these two last movements this is indeed the mode of measurement usually adopted.

In the same way, this vertical axis should be taken as the 0° of the scale in the measurement of rotation of joints, movement inwards and outwards around this being measured in the case of the joints of the limbs, movement to the right and to the left in the case of the joints that occupy the sagittal plane (joints of the head and spine).

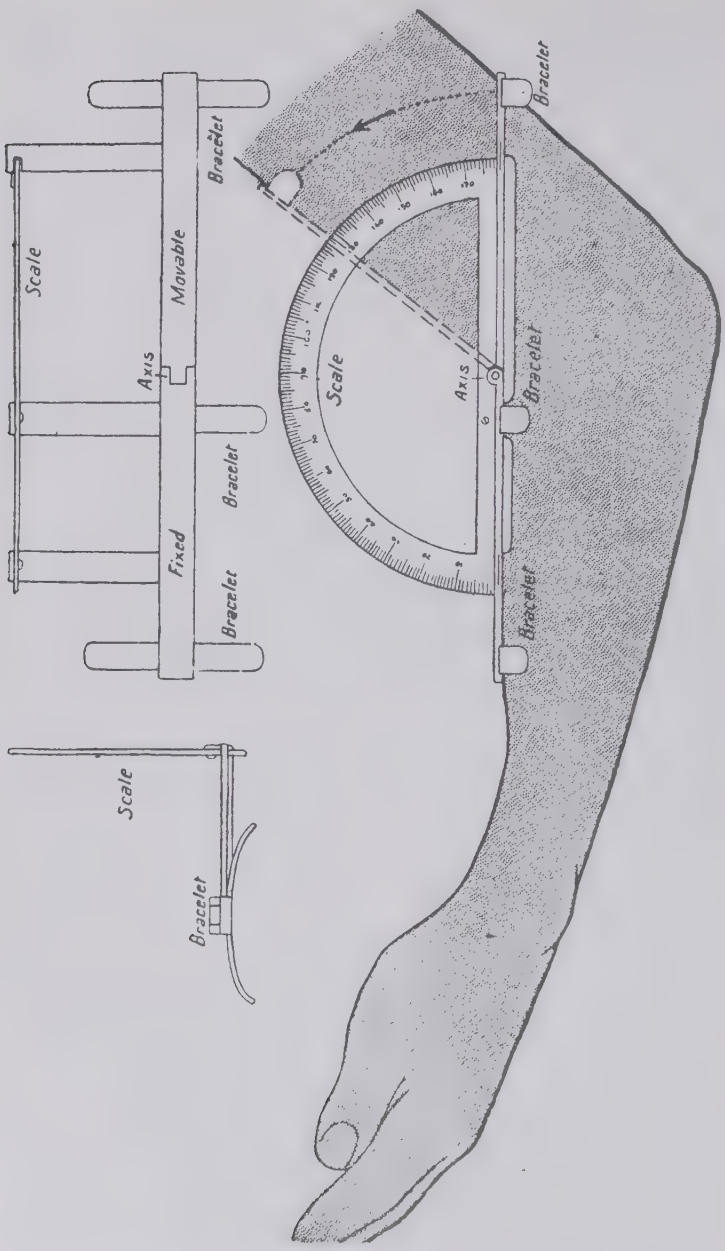
The very simple goniometer represented on page 18 is that used by Dr Schaer in the physiotherapeutic department at the Grand Palais, of which he is in charge. It consists merely of a simple metal hinge, to the far end of each lever of which is attached a bracelet that half encircles the corresponding segment of the limb. Projecting out on one side of these levers are three cross-bars, two below and one above the level of the hinge. To the two first is fixed a semicircular scale subdivided into 180°; the third abuts against this scale, and thus indicates the size of the angle at which the joint is fixed.

The axis of the hinge is placed opposite the line of the joint, the two bracelets are fixed on the corresponding segments of the limb respectively above and below the joint, and the reading on the scale gives accurately and at a glance the range of movement, active or passive, that is present.

Operative Procedures.—Having thus outlined the indications for treatment, let us see what operative methods are at our disposal for their fulfilment.

1. *Cases of ankylosis in mal-position.*—For the correction of this we can

(*a*) have recourse to forcible manipulation. This is effective, however, only in cases of fibrous ankylosis, and in many of these the possibility of its perform-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ance becomes obvious only at the last moment, when the patient is under the anæsthetic and everything is ready for an open operation.

(*b*) remove by open operation the cause of the ankylosis. This consists either of the resection of a limited osseous outgrowth, as in cases of extra-articular bony ankylosis or *ankylose cerclée*, or in the case of true intra-articular synostosis, of a full typical resection of the joint itself.

(*c*) divide either by osteotomy or by osteoclasis one of the bony levers of the joint, and by subsequent manipulation of the limb below the seat of this fracture place it in the desired position.

2. *Cases of ankylosis in good position.*—In these cases the question has to be decided whether it is better to be content and leave the joint ankylosed, or to attempt by surgical intervention restoration of the joint mobility.

In the lower limb, where considerations of stability, of support of the body weight, are all-important, the general rule should be to be content, to refrain from interference in cases of ankylosis in good position; even indeed in cases of ankylosis in mal-position in which we are forced to operate, we should deliberately aim at the production of a true bony ankylosis in the corrected position.

In the upper limb the problem is not so simple; it is complicated by rather different conditions, since here mobility is at least as important as stability. In cases of ankylosis in bad position, correction of this by resection of the joint gives at the same time an opportunity of attempting to regain a part at least of the former range of movement; where restoration of mobility is deliberately aimed at, as

in cases of ankylosis in good position, resection of the joint will become necessary.

It is in connection with the elbow joint and the shoulder joint that the functional results of ankylosis in good position and those of late secondary resection of the joint for the sole purpose of restoring mobility have to be compared; in this connection, however, no general rules can be here laid down.

I will only point out the necessity for the exercise of caution in the performance of open operations, or even of subcutaneous osteoclasis or manipulations that involve tissues formerly the seat of a suppurative osteomyelitis. We learned the necessity of this long ago in connection with the spontaneous osteomyelitis of adolescence; and we have found out that the infection of war wounds survives in a latent form the healing of the wound over even longer periods. We have, then, constantly to beware of recrudescence of the infection, so that in doubtful cases of ankylosis in which the functional utility is fair we should incline towards abstention from active intervention; in any case we should always postpone as long as possible any operation considered advisable or necessary, for time is the chief agent in the complete sterilisation of these healed foci of osteomyelitis.

In order to institute a useful comparison between the functional results of ankylosis and those of resection of the same joint it is necessary to pick out cases of the former condition as of the latter in which the musculature and the remaining joints of the limb are in good functional condition. In the case of the elbow joint it is the state of the hand and of the wrist that from this point of view, and as regards the

future usefulness of the limb, is all-important; moreover, this depends very much less on the operative methods that have been adopted, on whether resection has been performed or not, than on the involvement either in the original trauma or in the subsequent infection of vessels, muscles, and nerves, and also in cases in which such early lesions have been practically identical, on the attention that has been bestowed on the rest of the limb during the period of healing of the wounds. It would be unfair to compare in the upper limb a resection that has been skilfully performed but of which the after-treatment has been neglected, the remaining joints of the limb having been allowed to remain immobile and grow stiff in a sling, with a case of ankylosis in good functional position, in which, however, due attention has been given to the full use of the other joints of the limb, and notably to those of the hand; and the converse is equally true. In connection with disabilities in the hand, in cases of resection of the elbow joint, I often wonder whether in many more cases than is usually thought the surgeon is not responsible for the lesion of certain of the nerve trunks that lie in close relation to this joint, especially of the ulnar nerve. Of course one will say that such a thing never occurs at the hands of any surgeon worthy of the name; the fact remains that occasionally it does occur even with most skilful and experienced operators, and nowadays all who operate cannot be so described. I will compare, then, the cases of ankylosis that I have seen with cases of primary resection at the front and with cases of secondary resection for acute suppurative arthritis, even although it is not always easy to ascertain to

which of these categories a case belongs. We shall see that in general the functional result of such resections is far from ideal. Not in the least does this mean that such operations are to be condemned on principle; it is meant only as a warning concerning the common defects presented by such cases; it should always be remembered that these resections have saved the patients' lives, have been performed strictly as an alternative to amputations, and as such have been of signal service to the patients, have been the means of preserving the use of a hand that at the best is perfect, at the worst of fair utility, and of an elbow that, supported by a light apparatus with lateral hinge joints, is infinitely more useful than the best artificial arm. At the worst in these cases the surgeon has ample time in which to decide on late amputation should the limb thus preserved prove to be less useful than a good artificial arm.

But I am encroaching on the study of individual cases. I will now pass on to consider these in detail.

2. Ankylosis of the Fingers and Toes

(*a*) *The Fingers.*—Whether the affected joint be the metacarpo-phalangeal or an inter-phalangeal, the occurrence of ankylosis with lateral deviation of the finger distal to the lesion is in most cases quite incompatible with the carrying on of a manual trade, and the only rational treatment consists in amputation; this should be so planned as to conserve as great a length of stump as possible and as is compatible with a good covering for the bone end and a good position of the scar. A palmar scar should always be avoided, as should also a terminal scar in cases where, as in

inter-phalangeal amputations and in ex-articulation of the metacarpo-phalangeal joint of the thumb and of the index finger, the end of the stump must be prepared to bear a certain amount of pressure. In planning the flaps, whilst it is necessary to pay particular attention to the position and extent of the scar of the initial wound, yet one should adhere as closely as possible to the classical operative text-book directions (palmar flap with dorsal scar for amputations through the phalanges of the fingers and thumb, simple dorsal racquet incisions for ex-articulation of the metacarpo-phalangeal joints of the middle and ring fingers, excentric palmar flaps for ex-articulation of these joints of the index and little fingers). In cases where after primary incomplete amputations a tender adherent terminal scar exists, one is often forced to shorten the stump in order to get a good covering for the end of the bone and a satisfactory position for the scar.

In cases in which no lateral deviation of the finger exists, ankylosis in flexion will almost always be found to be most disabling, and this in an increasing degree the nearer the ankylosed joint lies to the root of the finger; there is, for instance, but little disability in such ankylosis in flexion of the terminal phalanx, but it becomes considerable in the case of the middle phalanx, serious where the metacarpo-phalangeal joint is the seat of the ankylosis. Wherever this deformity interferes with the working use of the hand, the only reasonable treatment consists in amputation through the ankylosed joint. Osteotomy followed by fixation in extension is not to be recommended, for ankylosis of either of the two proximal phalanges in extension is in the case of a manual worker quite as great a

disability as their permanent flexion. We need not consider the terminal phalanx, for the loss of it is quite negligible. In other words, a finger that remains stiff and projects out during flexion of the others simply catches on everything and gets in the way.

Besides, in the case of war wounds ankylosis of a finger joint is usually complicated by the presence of adherent scars, and by such loss or adhesion of tendons as serves to render ordinary conservative methods quite impracticable.

In cases too where a finger remains stiff and useless simply from division of its tendons, amputation is indicated whenever tendon suture is obviously out of the question or has failed. Where, however, passive flexion or extension of the finger is possible, the patient often learns to get the finger—immobile though not necessarily stiff—to follow the movements of its neighbours; although, even in such cases, occasionally the hand worker finds that he is better off without the finger.

In war surgery as in industrial accidents it is common to meet with cases of multiple lesions of the hand—ankylosis, peri-articular stiffness, partial or complete amputation, tender and disabling palmar scars occurring together in different fingers of the same hand.

No precise general rules can be laid down for the treatment of such cases; it can merely be said that during the period of healing one should adopt as conservative an attitude as possible, and that when healing has occurred everything should be done to retain or regain the power of opposition of the thumb so that the patient is able to pick things up; by

excision and plastic operation to get rid of disabling scars; to improve the general condition of the finger stumps; and to remodel a useful finger out of the scarred and tense mass of skin that is binding together two fingers into one, etc.

In the case of the thumb, conservative measures should be pushed to their extreme limit.

(*b*) *The Toes.*—A stiff toe that projects "out of the ranks" in any direction, whether flexed, extended, or overlapping its fellows either above or below, interferes with the wearing of the boot, and should be amputated. Even simple permanent flexion of a terminal joint constitutes a serious disability.

Hallux valgus should be treated by such a resection of the head of the first metatarsal bone as does not interfere with its important function of transmission of such part of the weight of the body as passes through the antero-internal part of the foot. I believe, however, that the walking disability resulting from amputation of the great toe with part or the whole of its metatarsal bone has been greatly exaggerated; on the other hand, I have seen patients in whom the adoption of conservative methods has resulted in ankylosis with an upward and inward projection of a great toe, the removal of which with the anterior part of its metatarsal bone should long before have been carried out.

If but one or two toes remain unamputated it is better to remove them also, for as long as the scar is situated well on the dorsum of the foot, amputation of all five toes gives an excellent functional result.

3. Ankylosis of the Wrist Joint

(*a*) *The position of election for ankylosis.*—There exists a considerable difference of opinion as regards the relative functional utility of ankylosis at about 45° of extension and ankylosis in the straight line.

The arguments put forward in favour of the extended position are, that it has been shown by the use of Marey's tambour that with the hand in this position a better and stronger grip is obtained on an object or implement, and that it is in this position of the wrist that almost all manual labourers perform their work. But in ordinary life this is an inconvenient position; that of ankylosis in the straight line is better suited to the essential requirements of every-day life. For choice, however, one may allow 15° to 20° of extension.

(*b*) The natural or instinctive position assumed by the wrist and hand in a patient suffering from inflammation of this joint is that of flexion, and unless precautions be taken to prevent it, this is the position in which ankylosis will take place. Such is the almost inevitable result of suspending the arm on the chest in a sling.

(*c*) During treatment this is the position against the adoption of which it is necessary to guard by splinting all cases in which, because of the presence of suppuration or the disposition of the wounds, the application of a plaster is out of the question. As soon as such becomes practicable, however, some means has to be devised, in the first place, of getting the forearm into supination, in the second, of slightly extending the wrist joint. Where necessary, this may be done under an anæsthetic. Further on (*vide*

page 297 and following) I will deal with the necessity for the earliest possible mobilisation and use of the fingers.

Cases of ankylosis in flexion with preservation of active movement of the fingers should be treated by resection of the joint; long ago Ollier demonstrated that in this way free movement at the wrist joint can be obtained. Personally, however, I have not met with any case of this sort; ankylosis in flexion—a condition the careful surgeon will almost always succeed in avoiding—is practically always the result of neglect, and under these circumstances a concomitant stiffness of the fingers will have inevitably occurred, thereby rendering the performance of such an operation quite useless.

Immobilisation of the wrist joint in flexion is, however, sometimes unavoidable; for example, in order to maintain the reduction of the fragments in certain simple fractures of the radius. Such should always be of very short duration, and corrected, under chloroform if necessary, as early as possible.

4. Ankylosis of the Forearm

In other words, loss or limitation of the movements of pronation and supination.

(*a*) *The position of election for ankylosis* in cases where all movement is suppressed is that of semi-pronation; full pronation and full supination are alike positions of considerably greater functional disability.

Where the ankylosis is incomplete, the position is to be regarded as favourable when, whatever the amount or direction of the movement (pronation or

supination), this position of semi-pronation can at any rate be reached.

(*b*) *The position instinctively assumed*, whether the bones are fractured or not, is, when the patient lies recumbent with his arm by his side, that of full pronation ; that of semi-pronation where, the patient recumbent or erect, the elbow is flexed to a right angle and the forearm is supported across the chest in a sling. Unless precautions to the contrary be taken, union in this latter position of the lower fragments is likely to take place in fractures, simple or compound, of the bones of the forearm; and especially in fractures of the radius.

The position of election in which the forearm should be maintained during treatment will depend then altogether on whether return of movement is to be expected or not.

In cases of suppurative arthritis of the elbow joint, in which ankylosis, complete or almost so, is certain to occur, the forearm should be fixed in semi-pronation. On the other hand, in cases of fracture it should be immobilised as early as possible in the position of full supination. In these cases of fracture a return of at least a great part of the range of movement is to be expected. If this position of supination be not assured, if the case be left more or less to itself, the lower fragments of the fractured bones will assume a position of partial pronation in relation to the supinated upper fragments, and, although the actual process of union may proceed satisfactorily, a form of mal-union will result, the lower fragments remaining permanently pronated ; in this way a permanent loss or impairment of the power of supination of the hand, active and passive, is brought about. Such condition

only too often results from the frequent immobilisation in semi-pronation of such fractures in plaster—a permanent persistence of the semi-pronated position and a corresponding permanent limitation of the range of supination.

For other reasons also this position of supination is desirable : in it the two bones of the forearm remain parallel and do not cross ; and in addition it is in this position that the width of the interosseous space is greatest. Apart from the form of mal-union or *décalage* just described, the chief cause of disability to be guarded against in fractures of these bones consists in an excessive formation of callus that, encroaching more or less on the interosseous space, limits sometimes to almost complete suppression the movements of pronation and supination ; or else the occurrence of a complete synostosis between the two bones, resulting again of course in complete loss of all such movement.

Radiographic examination alone is capable of accurately diagnosing such lesions ; surgical intervention alone can cure them. This should consist of :

1. Simple osteotomy with subsequent immobilisation in full supination in cases where union of the lower fragments has taken place in pronation.

2. The removal of such excess of callus as by encroaching on the interosseous space is interfering with the range of movement.

3. In cases of synostosis, resection of the bridge of bone uniting the radius and the ulna.

The indications for the performance of each of the three of these operations should be regarded not as absolute but as relative to the degree of the mal-union and to the extent of the professional disability.

5. Ankylosis of the Elbow Joint

(*a*) *The position of election for ankylosis* of this joint has been much debated. With some surgeons it is the right angle, or even a slightly acute angle, with the forearm in semi-pronation ; with others it is an obtuse angle somewhere between 125° and 135° of extension, the forearm being fully pronated.

The former have in their minds the performance of the necessary common acts of everyday life, such as eating, dressing, etc. ; the latter are almost wholly preoccupied by considerations connected with the patient's occupation, for example, of the force necessary in the use of a plane or of a file ; and the position of ankylosis that they recommend is really that adopted by most manual labourers in their daily work.

Any position between 135° of extension and the straight line is incontestably bad ; the limb remains practically useless even in cases of incomplete ankylosis in which there exists some range of movement within these limits.

(*b*) *The instinctive position of rest* being that of 135° of extension, a difficult question to decide is whether in the course of an inflammation of the elbow joint one should respect this naturally assumed position or interfere with it and insist on fixing the joint instead at a right angle.

Ankylosis in complete extension will always be avoided by a careful surgeon ; at a favourable moment during the healing of the wound he will take steps to correct such a position.

From my personal observation of cases of actual ankylosis of the elbow joint, most patients seem to be better served by the right-angled position ; in time

it seems to become better adapted to the conditions of their work than the obtuse angle ever becomes to the performance of the essential acts of everyday life. Hence I am accustomed to fix in this right-angled position all elbows likely to become ankylosed, irrespective of what the special occupation of the patient may be. As, moreover, in most cases free use of the limb is allowed before complete consolidation of the synostosis has taken place, the mere weight of the limb may usually be relied on to open out the angle of the elbow a few degrees in the direction of extension, so that in this way one has always to count on a probable future loss of these few degrees of flexion.

In some cases the occurrence of incomplete ankylosis is to be anticipated; for example, in cases of supracondylar fractures of the humerus with forward displacement of the upper fragment. In such the excess of callus that is formed will only too effectively interfere with the subsequent attainment of full flexion of the elbow. In this condition, then, the limb should be immobilised, with the elbow joint acutely flexed, for this is the position most likely to maintain the reduction of the fragments; besides, in such cases it is always more difficult to regain the full range of flexion—certainly the more useful of the two movements—than it is the full range of extension. In the restoration of this latter range, moreover, the weight of the forearm and hand can always be counted on as assisting.

(*c*) The operative methods at our disposal for the *redressement* of an elbow joint ankylosed in malposition are two: (*a*) forcible correction by manipulation; (*b*) resection of the joint. Corrective osteotomy is never indicated.

(*a*) Forcible mechanical mobilisation, introduced in the pre-antiseptic days, is now no longer used. Correction by manipulation is nowadays confined to certain cases of firm fibrous ankylosis. Up to a certain point radiography can furnish some indication of the possibility or the probability of its performance; but in many cases a final decision can be arrived at only at the last moment, when with the patient under the anæsthetic the persistence of a small amount of movement is detected. Hence in some cases although preparations will have been made for the performance of a full resection of the joint this will be proved to be unnecessary, correction by forcible manipulation being found possible. Where a considerable amount of peri-articular induration with an extensive adherent posterior scar exists, this forcible *redressement* may result in extensive laceration of the cicatricial tissue, a laceration that may even involve the partially obliterated joint cavity. This happened to me in a case of ankylosis of the elbow in full extension in which the condition of the hand was excellent. Healing of the wound proceeded slowly but smoothly, and a useful arm, ankylosed at a right angle, resulted.

(*b*) Joint resection, when performed with the limited object of an improvement in the position of the ankylosis, consists really of a cuneiform osteotomy of the synostosis. This removal of bone, whilst being as economical as possible, should always be carried out strictly sub-periosteally, so as to retain at the seat of the resection a maximum of osteogenetic tissue. I will discuss later the question,—in what class of case is one justified in aiming at restoration of mobility in performing a resection that is really an arthroplasty.

The indications for the performance of *redressement* of ankylosed elbows may be gathered from what I have already said; consequently they become absolute only in cases in which the position of ankylosis exceeds 135° of extension. In all other cases the wishes of the patient and the nature of his work should be taken into account. I will add that whilst I have never been asked by a patient to alter the right-angled position, I have several times been requested to convert an obtuse angle into a right angle.

Cases of incomplete ankylosis with retention of movement between 135° of extension and full extension should be treated as cases of complete ankylosis in a position anywhere between these two points; where, however, there exists movement between 135° and 90° of extension, operation is not indicated except in such cases—which, however, are not met with in war surgery—of limitation of flexion by the forward projection of a buttress of the upper fragment of a supracondylar fracture; such a cause of limitation of joint movement is easily removed without actually opening the joint itself.

(*d*) *Resections that aim at restoration of mobility.*—When performed in a certain definite manner, resection of the elbow joint may be followed by a return of mobility, by the formation of a pseudo-arthrosis or ne-arthrosis—a fact known long enough ago, for remarkable examples are to be found cited in Ollier's immortal work, *Traité des Resections*. In my opinion it would be decidedly wrong because of the occurrence of such cases to make a regular practice of this operation, whether performed early to obviate ankylosis, or late after ankylosis has become an accomplished fact.

I have seen at the Grand Palais, both in the physiotherapeutic department and in the depôt for the supply of surgical appliances, a considerable number of early primary resections of the elbow joint. Where the original destruction of tissue had not been great and the nerves of the limb had escaped, where the operation had been well performed and the after-treatment adequately carried out, the result was in some cases good in the sense that the movement of the fingers and of the wrist were intact and strong, active flexion of the elbow was stable, and the condition of the shoulder excellent.

The whole point seems to consist in operating before the muscles have had time to waste and undergo degeneration, and also in the institution of muscle training and treatment at the earliest possible moment after the operation. It is also, however, of great importance that the surgeon should have been trained in the practice of bone surgery in order that a strictly sub-periosteal removal of the fragments and regularisat on of the bony ends by means of the saw should be carried out. It should not be forgotten, moreover, that all surgeons do not possess this qualification; again, it is inevitable in war conditions that those who at the front perform the operation are unable themselves to take charge of the after-treatment, since evacuation before healing is complete is unavoidable. Hence the frequency of cases that fall considerably short of the standard that I have described, cases in which the function of the hand is but fair and active flexion of the elbow remains weak or is absent altogether.

Even if, however, I restrict examination to cases that on the whole show a good result, those, for example,

that have been exhibited at the Société de Chirurgie by surgeons who regularly and systematically perform this operation, and have hence a large experience of it, the fact remains that I have so far seen no case in which a certain amount of lateral mobility was not present, or in which the power of active extension of the joint had been retained. Almost all were in effect "flail elbows," in which, although in many active flexion was good and strong, yet extension was merely passive, so that whenever the extended arm was raised beyond the horizontal the action of the triceps was insufficient to hold the joint in extension against the action of gravity, and so the forearm immediately and passively dropped again into the flexed position.

Hence in the majority of the patients who were manual workers an appliance with lateral steel supports and hinges, and even in some cases with ratchets, became necessary. Experiments carried out at the Grand Palais by Nepper and Vallée with Marey's ergograph have definitely proved that the muscular strength of the arm is always greater in cases of ankylosis than in the best cases of resection.

Taking all things into consideration, many of these cases, I repeat, are nevertheless very remarkable; by an extensive removal of loose bone fragments—so extensive as to render the occurrence of ankylosis impossible—amputation of the limb has been avoided, and in addition to life, a limb remains infinitely better than an artificial arm; this is true even in cases in which, because of the extent of the initial tissue destruction or of the severity of the infective complications, but a limited amount of use remains to the hand; at the worst in such cases one can always

perform amputation later should it become necessary on account of causalgic or trophic trouble.

It is not, then, fair to compare the results of these extensive early primary resections with those of secondary resection for suppurative arthritis or of late orthopædic resection in cases of ankylosis.

But already the facts appear to me to demonstrate that it would be quite wrong to systematise into a routine the performance of this operation of primary resection, to resort to it at once as a prophylaxis against suppurative osteo-arthritis and in order to avoid the muscular wasting that in the long run of such resections forms the most important element in the prognosis, or to perform it in cases of but moderately extensive shattering of the bone—cases often with but little or no infection.

I am not ignorant of the teaching of those who recommend this operation, that joint resection is the most effective method of joint drainage; I grant that it is. Can we be quite certain, however, that so drastic a method of drainage is really thus necessary in the treatment of sepsis in the case of the elbow joint? As far as preservation of life goes, I unhesitatingly affirm that it is not. I have performed secondary resection in none of my cases of elbow wounds, and all have survived with a condition of hand and shoulder that corresponded strictly with the extent and nature of the original wound; in all, it is true, there exists ankylosis at a right angle, but I consider from what I have seen of the results of resection that there is no necessity for me to repent of this.

These remarks are meant in no wise as a criticism of those surgeons at the front or at the base who perform free resection in cases of either extensive

bone comminution or of severe sepsis; there is room for a difference of opinion among surgeons of equal worth as to when the necessity for an operation has arisen. I only say that as regards myself I am not in favour of this operation, for its performance very often results in excessive mobility of the elbow, and that, in my opinion, is always functionally inferior to firm ankylosis in good position.

As regards the restoration of mobility in an elbow already ankylosed by a late resection that includes a wide sub-periosteal removal of bone, this can undoubtedly be accomplished, and the success in many cases is even remarkable; it should not be forgotten, however, that a permanent false joint does not always result, that in some cases a recurrence of the ankylosis takes place.

One is certainly justified in attempting this, however, in the case of patients who are not going to perform hard manual work, and in whom a resection for mal-position is in any case indicated. But from what I have seen of the results of other surgeons, it would take a very special combination of circumstances to persuade me to attempt such an arthroplasty in the case of a patient with ankylosis in good position. I am not denying the occurrence of remarkably successful cases; but I certainly insist on the necessity for the recognition of the failures, of the occurrence of cases in which the joint, in so far as the presence of lateral mobility and the absence of strong active flexion go, remains weak and flail; of cases in which a recrudescence of the infection takes place, with the formation of abscesses among the flexor muscles of the forearm that result in their subsequent sclerosis and retraction; of the cases that

I have seen at the Grand Palais of arms definitely crippled that before the operation were firm and strong; of the cases I have met at the Société de Chirurgie, which although there has been primary union of the operation wound, yet have seemed to me to be on the whole not better but worse off than they were before the operation. Besides, who, operating in the seat of an old war wound, can with certainty guard against a recurrence of osteomyelitis?

My views on this subject may be summed up and expressed as follows:

1. Cases of ankylosis at a right angle should never, except under very special circumstances, be subjected to operation.

2. In cases of ankylosis in a position between 135° and 180° of extension, the indications for correction should be regarded as absolute; where the position of ankylosis lies between 135° and 90° of extension, the indications for intervention should be regarded as dependent on the occupation and wishes of the patient.

3. Where the ankylosis is fibrous, the correction should whenever possible take the form of manual *redressement* and not of joint resection.

4. Whenever resection is undertaken for bony ankylosis, it should be remembered that mobility is often gained at the expense of stability.

6. Ankylosis of the Shoulder

(*a*) *The general mechanism of the shoulder movements.*—The functional value of the shoulder joint in any case may be regarded as being strictly proportional to the range of abduction present in that case; in

other words, the disability consequent on disease of this joint may always be estimated by measuring the distance by which, when the patient raises his hand up to or beyond the level of his head, the arm falls short of the vertical position—the limit of the range of normal abduction.

In order fully to understand this movement of abduction of the arm it becomes necessary to study it carefully, to analyse it, and to decide what part in it is played by the scapulo-humeral or shoulder joint and what by the scapula and by the clavicular joints.

On manipulation of the shoulder joint—the scapula meanwhile being fixed by its lower angle in the vertical position in a vice—the observer will find—what indeed the extent of the cartilaginous covering of the articular surfaces of the shoulder joint would lead him to expect—that the movement of direct abduction of the arm in the frontal plane comes to an end as soon as the humerus reaches the horizontal—in adults even when it is still a few degrees short of this level. The lower axillary part of the capsule is at this moment stretched to its utmost, and effectually prevents further abduction of the arm; thus the joint has become "blocked," and as the scapula is already fixed, all further movement in this direction becomes manifestly impossible.

But in the cadaver and also in the normal living subject there is of course no such immobilisation of the scapula. This bone is normally kept in contact with the chest wall solely by muscular action, being suspended from the clavicle through the ligaments of the acromio-clavicular joint. The clavicle, abutting internally against the manubrium sterni, can normally

be raised higher than the horizontal level; on the other hand, resting, as it does, on the first rib, it cannot descend below this horizontal level.

If then, having come to the point when the shoulder joint is "blocked," and at which the humerus has become horizontal, the observer now persists in the passive abduction movement of the humerus, he will find that all further abduction of the arm is accompanied by and due to a rotation of the scapula around its supero-external angle or neck, which in the meantime remains a fixed point; the acromion becomes elevated, and the clavicle slopes upwards and outwards; the long axis of the scapula, hitherto vertical, now runs obliquely downwards and outwards; its vertebral border of course shows the same obliquity, and its inferior angle, becoming slightly elevated, is at the same time displaced considerably outwards towards the axilla.

The active movement of abduction, taking place at the shoulder joint, and resulting in elevation of the arm to the horizontal, is effected by the action of the deltoid; such elevation may be pure abduction, an outward and upward movement strictly in the frontal plane, carried out by contraction of all the fibres of this fan-shaped deltoid muscle; or it may be accompanied by flexion of the shoulder joint, the result of the action of the anterior deltoid fibres assisted by the pectoralis major; or again the arm during elevation may be kept behind the frontal plane—in other words, the abduction is accompanied by extension, although the range of this combined movement is but slight—and this is effected by contraction of the posterior part of the deltoid in company with the latissimus dorsi and the teres major.

The muscle responsible for the rotation of the scapula during the second part of abduction of the arm is the serratus magnus.

In the living subject the passive movement may be investigated in the following manner: the subject sits astride a chair and displays his back to the observer, who, seizing the lower angle of the right scapula between the thumb and index finger of his left hand, with the other abducts the right arm of the subject from alongside his body. At a certain definite moment he will feel the angle of the scapula commence to slip from between his fingers in an outward direction towards the axilla. The moment of commencement of this scapular rotation marks the limit of the mobility of the head of the humerus on the glenoid cavity; in other words, the limit of abduction at the scapulo-humeral joint.

(*b*) *The movements in ankylosis of the shoulder joint.* —When the shoulder joint is either completely or incompletely ankylosed abduction of the arm takes place by scapular rotation, either wholly and from the outset in the case of complete ankylosis, or partially and after the completion of as much of the normal range of abduction as is possible at the incompletely ankylosed joint.

An examination carried out as described above is indispensable for a correct appreciation of the amount and nature of this movement in each individual case. As a matter of fact, whenever the shoulder joint is completely ankylosed a certain amount of relaxation of the ligaments of the clavicular joints gradually takes place, and this results in a compensatory increase in the range of the scapular rotation that, so long as the serratus magnus remains in strong action, goes far

to diminish the amount of the functional disability from the articular lesion.

This is what takes place when the ankylosis of the joint has occurred with the arm in adduction, the vertebral border of the scapula remaining vertical whilst the arm hangs close to the side. Where, however, the ankylosis has taken place in abduction, the vertical position of the arm will be found to correspond to an inward and downward obliquity of the vertebral border of the scapula, so that the inferior angle, whilst occupying a slightly higher level, has come to lie distinctly nearer the middle line. In such a case, upon the commencement of abduction of the arm from the side the scapula is in a position of adduction; consequently, and to a corresponding extent, its range of abduction will be diminished.

Ankylosis of the shoulder in internal rotation is compensated for by carrying the point of the shoulder backwards; this gives an antero-posterior range of movement to the claviculo-scapular apparatus, whilst at the same time there is an opening out of the angle between these two bones. Ankylosis of the shoulder joint in external rotation (a much more serious disability) is compensated for by carrying the point of the shoulder forwards and rounding the back. In this way is created a postero-anterior range of movement for the clavicle and scapula; at the same time, the angle between these two bones narrows to become more acute.

I have described the scapular mechanism at length, because I wish to point out how great an importance should be attributed to the active and passive movements of the scapula in coming to a decision as to the degree of the disability that is present; and this

all the more, because certain military instructions forbid its being taken into account. As a matter of fact, from the point of view of many professions and trades, ankylosis of the shoulder even when complete constitutes but a moderate disability provided that the normal movements of the scapula are intact; on the other hand, even when incomplete, it constitutes a grave infirmity when the scapula is either fixed by scars or adhesions or immobilised by paralysis or muscular weakness.

(*c*) *The position of ankylosis.*—Ankylosis almost always takes place with the arm in the vertical plane, abducted to 15 or 20 degrees, and in slight internal rotation; in other words, in an attitude in which compensation by the scapular movements remains adequate. Hence in the case of the shoulder joint there exists no antagonism between this position of election of ankylosis and the instinctive position of repose adopted by the joint during inflammation.

As soon, however, as the period of painful distension of the joint has passed, and especially when the patient commences to get about, the weight of the arm spontaneously effects the slight amount of correction that is necessary in its position, and this before the long-delayed process of consolidation of the synostosis has become complete.

As a matter of fact, I have never seen a case of ankylosis of the shoulder joint in which correction was at all necessary.

I have, however, seen—in civil work, but not in military—several cases of mal-union with angulation of the upper part of the humeral shaft, in which it became necessary to perform osteotomy followed by immobilisation in abduction, so that the long axis

of the lower fragment could again come into line with that of the upper.

(*d*) I believe that the majority of surgeons do not approve of attempts to restore mobility in the case of ankylosis of the shoulder joint by the performance of an arthroplasty.

There are, it is incontestable, cases in which such resection of the shoulder joint has been followed by recovery of perfect function, with the formation of an almost perfect ne-arthrosis. For example, I have published a case of a boy who as a baby had had resection performed for osteomyelitis (a procedure, however, of which I cannot approve), and possessed at fourteen years a joint with perfect movement in every direction, and in addition a good development of the shoulder muscles.

In civil surgery this is, however, the only case of its kind that I have seen ; in war surgery, among the very numerous cases of resection that I have studied, resections that had been either primary or secondary and performed for acute suppuration, I have seen no such case.

Where the resection has not been very extensive it usually ends in ankylosis, and in this case the patient has not, in my opinion, very much to be dissatisfied about. Where, on the other hand, it has been extensive a pseudo-arthrosis nearly always results, with complete absence of all active movement of the arm on the body.

In the majority of such cases the deltoid has become atrophied or else has been in part destroyed, so that the arm hangs limp and flail in action as in repose. Where, however, the whole or a good part of this muscle has escaped the arm hangs flail in repose only, but

as soon as the deltoid contracts it raises the end of the humerus against the scapula; this furnishes a point of support for the use of the elbow and hand. But in either case all active power of abduction is lost. It is not possible to supply this action by means of any external support or appliance, and these have all a disadvantage of their own in that in order to support the flail shoulder they require to embrace the elbow, and so interfere with its range of movement. Hence it becomes only too obvious that the disability in pseudo-arthrosis of the shoulder is almost always infinitely greater than that of ankylosis.

I repeat that I have seen nothing but pseudo-arthroses result from resection of the shoulder joint; moreover, I am speaking not merely of the cases that have been referred for the supply of a surgical appliance (which is rarely of much use), for it might quite well be argued that the good results having no need of such would thus be missed; I am speaking also of the cases that have come to the centres of physiotherapy for muscle training. I may also add that very few cases of an even fair result have been shown at the Société de Chirurgie, where, however, many have appeared of resection of the elbow joint (which also, in my opinion, is practically always inferior to ankylosis in good position); and if there had been many, it is reasonable to suppose that some at least would have been exhibited there.

As regards primary resection, I will repeat what I said in the case of the elbow joint; that, in my opinion, it would be wrong to adopt it as a routine measure, or to complicate its performance by very extensive removal of bone fragments; that it seems to be better to be content to lose a little time, to

make sure first of ankylosis, and then to operate as economically as possible. At the same time, however, one gets the impression that a good number of these cases have by resection avoided a disarticulation through the shoulder joint, and in this case, where they possess the fair use of elbow and hand, they have much to be thankful for.

The position is the same as regards those cases of secondary suppurative osteo-arthritis which, threatening life without showing any evidence of abscess formation or of pus tracking down the arm, cannot be checked by mere arthrotomy followed later by partial successive removal of sequestra and bone fragments, with ankylosis as the end result; in these it often becomes possible to save the arm by performing resection. Now, many surgeons consider that such a course should be the rule, holding that resection alone can assure adequate drainage of a suppurating shoulder joint. In such cases it is true one can often carry out a subcapsulo-periosteal resection by simply removing with the chisel the head only of the humerus, the bone being divided at its anatomical and not at its surgical neck; but I do not think that there is much chance of this operation resulting in the formation of a stable ne-arthrosis. I believe indeed that firm ankylosis will very much more often result, but I am equally certain that such a procedure would result in the production of a good number of pseudo-arthroses with the pathological and functional features that I have just described.

Where, then, the performance of simple arthrotomy is sufficient to assure the life of the patient, I regard it as being by far the better operation, from the point of view of the future function of the limb; at any

rate, all that I can say is that I have by this means succeeded in curing all the cases of suppurative arthritis of the shoulder joint that have come under my care, and that all have ended in firm ankylosis.

It is on this account that almost all surgeons refuse to countenance the treatment of ankylosis of the shoulder by the performance of an arthroplasty—an operation that is exceedingly likely to end in a flail joint, especially as in all these cases there is never much chance of recovery of power in the atrophied or partly destroyed deltoid.

In cases of extensive loss of substance of both humerus and of scapula with widespread destruction of soft parts the arm often becomes drawn upwards and inwards against the side of the body by the retraction of a wide, deep mass of scar tissue; in this way is furnished in many cases quite a good point of support for the movements of the elbow and hand. Unfortunately, however, these cases are very often complicated by lesions, primary or secondary by compression, of the axillary vessels and nerves.

Where the condition of the muscles round the shoulder remains good despite extensive loss of substance of the humerus itself the upper end of the bone may be cleared of scar, and the pectoralis major and the deltoid may be reinserted into it; these muscles will thus be given a chance to resume their function of suspension of the weight of the arm. Such an operation occasionally gives a brilliant result, although the conditions that alone allow of this success are unfortunately but rarely realised.

7. Ankylosis of the Foot

The joints of the foot are so numerous, and their function so complicated, that a very accurate knowledge of their normal anatomy and physiology is an essential preliminary to the study of the mechanical consequences of their ankylosis in good or in bad position.

Now, this is a very important subject, for ankylosis in mal-position of the joints of the foot is a very frequent cause of very serious disability—disability that the exercise of but a little care and forethought could very often have succeeded in avoiding, and that but a slight amount of intelligent surgical intervention suffices to cure.

An investigation of details is here all the more necessary, because the performance of the operation of arthrodesis—the production of an artificial ankylosis—is very often rendered necessary by conditions of the foot that we shall study later, and we cannot lay down rules as regards its technique, nor specify its indications, unless and until we establish with great care what the normal movements of the foot really are, what are the favourable and what the unfavourable positions for ankylosis, and what is the functional value of the different varieties of ankylosis of the various joints. I shall, therefore, be excused if I accord to the foot the place of honour among the organs of locomotion.

A. *The Normal Anatomy and Physiology of the Foot*

A. The Architecture of the Foot.—When the foot is viewed in profile from one or other side its

posterior part will be seen to be formed by the two bones of the posterior tarsus, the astragalus superimposed on the os calcis. The anterior surfaces of these two bones will be at once seen to reach the same vertical and transverse planes, whilst behind the os calcis projects backwards beyond the astragalus for a distance corresponding to about one-third of its antero-posterior length.

Immediately in front of the os calcis lies the cuboid; anterior to the astragalus is the scaphoid, in front of which in turn lie the three cuneiform bones. These bones together form the anterior tarsus, and bear the five metatarsals, the inner three of which articulate one with each of the cuneiforms, the outer two with the cuboid.

These bones form a double antero-posterior arch, an outer resting on the os calcis and the two outer metatarsals, and an inner supported by the astragalus and the three inner metatarsals.

The line of the os calcis, which slopes upwards and outwards, is prolonged in the same direction by that of the cuboid, which, thus resting in the air, forms the keystone of the outer arch between its ascending part, the os calcis, and its descending, the two outer metatarsals.

Both ends of the external arch reach the ground. On the other hand, the posterior end of the internal arch, the astragalus, is supported not on the ground but on the os calcis. The head of the astragalus thus remains in the air above the ground internal to and above that of the os calcis, but in the same transverse plane; between it and the three inner metatarsal bones, which constitute the descending part of the arch, the keystone of the inner arch is formed by the

scaphoid and the cuneiforms. The inner arch, much more hollow than the outer, forms the middle portion of the inner border of the foot, to which it gives its arch.

In this way this inner border of the skeleton of the foot rises higher from the ground than the outer; in a transverse direction the posterior ends of the metatarsal bones and the bones of the tarsus that carry them form a transverse arch that rises higher from the ground, as one passes from without inwards, from the fifth to the first metatarsal bone.

B. The Articulations of the Bones of the Foot.—There exist three articulations between these groups of bones: (1) between the metatarsal bones and the bones of the anterior tarsus; (2) between the anterior tarsus and the posterior tarsus; (3) between the two bones of the posterior tarsus, the astragalus and the os calcis.

1. *The tarso-metatarsal joint of Lisfranc.*—Complicated as this joint is by the interlocking of the metatarsal and cuneiform bones—a fact of very great importance in operative surgery—it possesses but a very limited range of movement; the results of its ankylosis, of no practical importance, need not detain us. Before leaving it, however, I will describe the bony projections that mark the inner and outer ends of the line of this joint.

On the outer side the bulky tuberosity of the fifth metatarsal bone projects one finger's breadth backwards beyond the joint line. Internally and on the plantar surface the line of the joint lies 2 to 3 millimetres behind the tubercle of the first metatarsal bone.

2. *The mid-tarsal joint of Chopart and the sub-*

astragaloid joint.—Connected both anatomically and physiologically these two joints should be studied together, especially by the orthopædic surgeon, to whom they are of peculiarly great practical importance.

The os calcis is formed for about two-thirds of its length by a posterior portion that is obviously higher and wider than the anterior third; from this on its upper surface it is separated by a groove running obliquely forwards and outwards, which, moreover, is wide at its outer end, narrow at its inner. Behind and external to this groove on the upper surface lies an extensive articular facet that slopes inwards, backwards, and upwards—the upward element in this slope is often forgotten; in front and internal to the groove is another articular surface that belongs really not to the body of the os calcis at all but to an inwardly projecting shelf of bone that forms the lesser apophysis of the os calcis—the sustentaculum tali, which, as its name indicates, supports the head of the astragalus.

The anterior surface of the os calcis is transverse and consists of a facet that articulates with the cuboid; in a recess lies the anterior end of the sustentaculum tali, which terminates at a distance of about 15 millimetres from the scaphoid, to which it is united, however, by a powerful fibrous band, the "spring" ligament, the upper surface of which is coated with cartilage, and its inner edge reinforced by the sheath of the tibialis anticus. This is inserted into the infero-internal aspect of the scaphoid. The cartilaginous surface of this ligament is in direct continuity with that of the sustentaculum tali behind and with that of the scaphoid in front. Hence if the posterior part of a foot from

which the astragalus has been removed be viewed from above there will be seen (1) postero-externally a cartilage-covered surface sloping obliquely downwards, (2) in front of this a roughly-marked groove of triangular shape, and (3) antero-externally another cartilage-covered surface that as regards its posterior half (the ligamentous and sustentacular surfaces) is plane and horizontal, as regards its anterior part is vertical but concave (the articular surface of the scaphoid).

The astragalus consists of a large cubical posterior part or body, its upper surface shaped like a pulley (I will return to consider this later), prolonged forwards into a neck and head, the under square surface of which continues to occupy the horizontal plane, whilst the upper slopes sharply forwards and downwards. This bone bears a general resemblance to a snail, its head projecting forwards out of its shell and to one side (the inner); there even exists a short tail—the backward projection of the os trigonum—that receives the sheath of the flexor proprius hallucis; moreover, just as a snail on the move hollows out the front part of its body, so the under surface of the neck of the astragalus between the head and the body is hollowed out into a rough groove. Behind this groove lies a cartilage-covered articular surface; in front another, which however is continuous round a right angle with that on the anterior aspect of the head.

This being so, one can easily understand how this snail with the rounded back lies on the os calcis—the body of the one bone on the body of the other to form the posterior sub-astragaloid joint, the upward slope of which should never be forgotten; the grooves on the two bones lie opposite to and face

each other to form the non-articular sub-astragaloid tunnel or sinus; the head of the astragalus lying on the articular surface of the sustentaculum tali prolonged in front by that of the "spring" ligament, with its anterior surface fitting into the articular hollow of the scaphoid, so that by its anterior and inferior surfaces it is received into a scapho-gleno-sustentacular socket.

The sub-astragaloid tunnel or sinus is occupied and occluded by the powerful interosseous ligament, which consists of two distinct bands that bind the two bones most firmly together. The outer part of this tunnel being wide is easily accessible to the knife; the inner part, on the contrary, is narrow, and hence not nearly so accessible. It is from their outer side that these joints should always be approached by the surgeon.

Although the mid-tarsal joint of Chopart occupies a transverse plane between the bones of the anterior and posterior tarsus, *i.e.* between the astragalus and the scaphoid above and internally, between the cuboid and the os calcis below and externally, yet there exists a definite anatomical continuity between the inner astragalo-scaphoid portion of this joint and the anterior sub-astragaloid joint, the two together forming a single socket for the reception of the head of the astragalus; it will also be readily understood that there exists an intimate mechanical connection between this composite joint and the posterior sub-astragaloid.

A direct guide to the transverse line of the mid-tarsal joint is furnished by the plantar tubercle of the scaphoid, which projects beyond this line for a distance of from 2 to 3 millimetres. This, then, gives

the line of the astragalo-scaphoid joint; on the outer border of the dorsum of the foot the line of the calcaneo-cuboid joint lies in the same frontal plane, and a finger's breadth behind the tuberosity of the fifth metatarsal bone.

3. *The ankle joint.*—This joint is situated between the tibia and the fibula, which are bound together by strong ligaments to form a socket, into which fits the body of the astragalus, its upper articular surface being pulley-shaped.

This upper surface is not absolutely horizontal, but slopes slightly downwards and outwards; it is continuous over each border, with a cartilage-covered facet that articulates with the corresponding surface on the malleolus; the inner of these lies further forwards, but does not extend so far downwards as the outer, and its long axis is antero-posterior. Of course the relative shape and position of these facets correspond with the relative positions and shapes of the articular surfaces of the two malleoli, the outer of which lies on a plane more posterior but lower than that of the inner.

Without entering on a detailed account of the shape and insertions of the ligaments of the ankle joint, it should always be borne in mind that the anterior and posterior capsular ligaments are functionally negligible, that the stability of the joint depends on the lateral ligaments, each of which, fixed above to the tip of the corresponding malleolus, is formed on the same general plan, and consists of: (1) a superficial layer, trans-astragaloid, arising from the outer surface of the tip of the malleolus and inserted below into the os calcis; and (2) a second deeper layer that consists of two chief bundles, one anterior, fixed to the

neck of the astragalus, the other, posterior, and very powerful, attached to the " tail " of the astragalus.

The guides to the position of the joint line are furnished by the tips and anterior margins of the two malleoli.

It is just in front of the tip of the external malleolus, on the outer side of the foot, that the joint line of the posterior sub-astragaloid joint is to be looked for.

C. The Examination of the Foot.—I have already given some account of the relationship of the various bony prominences to the position of the lines of the joints of the foot. I have still to describe how these bony points are to be identified.

The observer should sit facing the sole of the foot, the patient meanwhile reclining with the leg fully extended and horizontal, and resting on the calf. The foot should be taken between the two hands in such a way that the thumbs meet transversely across the sole just behind the heads of the metatarsal bones and each index finger lies along the corresponding border of the foot. On palpating these borders with the tip of these fingers the surgeon will at once make out the tips of the malleoli, and on the outer side the tuberosity of the base of the fifth metatarsal bone (on palpating this outer border from behind forwards the tip of the finger will hook against this important bony prominence).

Along the inner border it is not so easy to make out either the tubercle of the first metatarsal bone or that of the scaphoid. These should be sought well on their plantar aspect; the best way to localise them is to run the tip of the finger along the under surface of the shaft of the first metatarsal bone and so reach its tubercle, then over the smooth plane

under surface of the first or inner cuneiform, and so on to the tubercle of the scaphoid. Absolute certainty in the localisation of these two points is of the greatest importance. Immediately behind and above the scaphoid lies the tip of the internal malleolus. In cases in which, through swelling of the tissues of the foot, such careful palpation of these two points is impossible, the tubercle of the metatarsal bone can always be found by taking the half-way point between the inner side of the point of the heel and the tip of the great toe; and where one of these points is missing, the measurement can be carried out on the other foot, and half of this measured forwards or backwards from whichever of these two points remains.

The projections formed by the tendons that surround the ankle joint are as follows:

1. Behind the external malleolus lie the two peronei tendons, that of the peroneus brevis in front hooking acutely round its point and coming to lie above, that of the peroneus longus below, a small tubercle on the outer surface of the os calcis. A longitudinal incision a few millimetres above the level of the tip of the malleolus will display without endangering the upper edge of this tendon.

2. Behind the internal malleolus lie the tendons of the tibialis posticus and of the flexor communis digitorum. Situated in front of the other, the tibial tendon winds round the tip of its malleolus in order to lie along the glenoid or internal calcaneo-navicular ligament, with which its sheath blends, and the internal lateral ligament, and so gains the tubercle of the scaphoid. The tendon of the common flexor disappears quite suddenly into the tunnel of the os calcis. As regards the tendon of the flexor proprius hallucis, which

passes behind the astragalus and under the sustentaculum tali, it does not here approach the surface, and hence cannot be palpated. It should never be forgotten that this muscle arises from the fibula, and the flexor communis digitorum from the tibia; consequently the two tendons cross in the sole of the foot. It is important to remember this in connection with disabilities of the toes following destruction of the muscular tissue of the calf.

3. Sloping obliquely forwards and inwards in front of the ankle and lying directly on the tibia is the taut tendon of the tibialis anticus, which thus reaches its insertion into the internal cuneiform bone. External to this tendon are to be found that of the extensor proprius hallucis, those of the extensor communis digitorum, and that of the peroneus tertius, in that order from within outwards. This last gains an insertion into the tuberosity of the fifth metatarsal bone. These tendons are held in place by means of an arrangement of ligamentous bands (the annular and fundiform ligaments), which are fixed to the hollow of the os calcis; when operating to display these tendons these ligaments should always be respected.

4. Behind and at a distance from the ankle joint descends the tendo Achillis separated from the edge of the malleolus on each side by a wide groove, that is always in any inflammatory condition of the foot or leg very quickly obliterated by swelling.

D. The Active and Passive Movements of the Foot.—The nature and directions of the movements of the foot is a subject that has lent itself to philosophical discussion, and this has resulted in a great confusion of nomenclature. The simplest system to adopt is the following:

Extension, when the point of the foot is lowered with elevation of the heel from the ground—the position of equinus.

Flexion, when the point of the foot is raised with a lowering of the heel—the position of calcaneus.

Internal and external rotation, when the sole of the foot looks respectively inwards and outwards.

The terms *varus* and *valgus* should be restricted respectively to adduction and abduction of the front part of the foot.

The alternate movements of flexion and extension take place at the hinge joint of the ankle. In the adult this joint has a normal range of between about 70° and 135° of extension, the position of 70° of extension corresponding to a position in which the long axis of the foot forms an acute angle with that of the leg.

Extension is carried out by the direct and powerful pull of the gastrocnemius and of the soleus, whose common tendon, the tendo Achillis, is inserted into the posterior aspect of the short arm of the lever of the foot formed by the os calcis. These are the only muscles that get a direct attachment to the bones of the posterior tarsus. Flexion is effected by the direct action of no such individual muscle; as a matter of fact there is no great need for strong direct flexor muscles, as in walking; flexion of the ankle joint is largely a passive movement. It is carried out, however, by the tibialis anticus and the peroneus brevis when their action on the anterior tarsus is accomplished; similarly by the extensors of the toes as soon as their extending action has become complete.

The alternate movements of adduction and ab-

duction of the front part of the foot, resulting in the positions respectively of varus and valgus, take place at the mid-tarsal and sub-astragaloid joints, which act in concert—a concert that is indeed on anatomical grounds inevitable :

1. With adduction is associated a certain degree of equinus (a lowering of the toes and of the front part of the os calcis), and in addition some internal rotation, by a tilting round its antero-posterior axis, of the os calcis, whose outer surface thus comes to look somewhat downwards as well as outwards. At the same time there takes place a certain amount of adduction of the anterior part of this bone, so that its antero-posterior axis inclines slightly inwards as well as forwards. With the foot in this adducted position the occurrence of flexion at the mid-tarsal joint would result in the formation of a typical pes cavus.

2. With abduction is associated a certain degree of calcaneus and of external rotation, with a movement of the os calcis the exact reverse of what we have just described ; this results in a tendency to flattening of the antero-posterior arch of the foot.

Hence the os calcis, following the movement of the anterior tarsus, pivots round and beneath the astragalus ; the interosseous ligament, connecting the two bones together, acts as a check on the rotatory movement. As we have seen, this ligament is quite taut and short at its inner end, and this serves as the fixed point around which the pivoting takes place ; whilst its outer part, being longer and looser, allows free play to the rotation of the os calcis round the fixed point. This movement of the os calcis may be compared to that of a ship swinging round

a fixed point between its two ends. In Farabeul's words: "The os calcis veers and pitches and—rotating round its long axis—rolls like a ship at sea."

Movement at these mid-tarsal and sub-astragaloid joints also takes place in the reverse direction; in other words, instead of the position of the front part of the foot influencing the movements of the os calcis, these can influence and change the position of the fore part of the foot; hence the tendo Achillis, besides being an extensor of the foot, is through its attachment to the os calcis an adductor of the front part of the foot.

With the foot in the varus position the scaphoid bone sinks down somewhat into the sole, so that its tubercle becomes less prominent, whilst, on the other hand, the head of the astragalus comes to project out on the dorsum of the foot. The reverse is true in the position of valgus; the head of the astragalus becomes difficult to make out on the dorsum, and the scaphoid tubercle again becomes prominent. The varus position is also associated with an increase in the width of the outer part of the articular spaces of these mid-tarsal and sub-astragaloid joints, so that in this position these joints are more accessible for the introduction of the knife from the outer side.

Contraction of the two tibial muscles is responsible for the assumption of the varus position of the foot, although the anterior has in addition a strong internal rotatory action. The direction of pull of their tendons corresponds to lines joining their points of reflexion forward from round the ankle joint and their points of insertion into the tarsus.

The muscles that pull the foot primarily and directly into valgus are the peroneus tertius and the

peroneus brevis; the extensors of the toes and the peroneus longus act only secondarily and indirectly. This last muscle, the peroneus longus, exerts its chief action on the base of the first metatarsal bone; its contraction results in a lowering of the head of this bone in a sort of movement of opposition. Hence, in the sole of the foot, its tendon acts as a ligament in maintaining the concavity of the arch of the foot.

The muscles inserted into the fore part of the foot may be compared to the reins attached to the head of a horse. When all act together and with equal force, flexion of the foot results; when those on one side possess the greater force, this balance is upset, and the foot is drawn over to the corresponding side.

Rotation inwards or outwards of the whole foot *en masse* around its long axis does actually occur; but this is, as I will endeavour to explain, a merely passive movement; such rotation of the whole foot, however, constitutes an attitude of great pathological importance. Ligaments are meant to allow a certain amount of play to a joint; actual contact of the articular surfaces is effected either by an active force—the tonicity or contraction of muscles—or by a purely passive force—the body weight—not by the direct action of ligaments. If ligaments were absolutely taut, stretched to their utmost, all joint movement would be abolished. Although, then, the ankle joint possesses only the active movements of flexion and extension, and the sub-astragaloid joint only that complex gliding movement that we have just described, there does exist at both these joints a certain range of passive movement allowing of passive rotation of the whole foot inwards or outwards, the astragalus being rotated in its mortise, and the os calcis likewise

turning beneath the astragalus. Such movement, however, is not really physiological, not capable of active utilisation by the living subject. If the reader attempt to perform it actively himself he will at once realise how slight and weak it is. But when passively carried out it at once becomes of wider range, and usually the younger the subject, the wider this range. The reader can prove its actual range in himself by standing first wholly on the inner border of one foot—the corresponding leg sloping downwards and outwards with the knee adducted—and then again on its whole outer border—the knee now abducted and the leg sloping downwards and inwards. In each case the weight of the body is responsible in the first place for this passive movement of rotation of the foot, and subsequently for the maintenance of this rotated position.

B. *The Action of the Foot in Standing and Walking*

(*a*) An imprint with lampblack of the sole of the normal foot shows that *during standing* weight is transmitted through the foot to the ground over a surface that includes the whole width of the heel in the posterior part of the sole, the whole length of the outer border of the sole, half the width of its middle part, and the whole width of its anterior fourth.

In points of bony support this represents the two posterior tuberosities of the os calcis, the whole length of the fifth metatarsal, and the heads of all five metatarsal bones. The chief part of the weight is, however, transmitted through the heel and through the heads of the fifth and first metatarsal bones; of these two

latter points the head of the fifth transmits the greater weight in the standing position, the head of the first during walking. The external arch of the foot is the arch of passive weight bearing, whilst the function of the internal arch is related to walking.

During standing the weight of the body has a constant tendency to flatten out the arch of the foot, to drive down the keystones of the arches (the cuboid, and especially the scaphoid); such would inevitably result in a deviation of the fore part of the foot into a position of valgus. This tendency is resisted not by the ligaments—ligaments will always in time yield to a prolonged strain—but by the tonicity of certain muscles, the short plantar muscles and the long flexor tendons, which act by tending to approximate the two extremities of the arch; in addition, as we have already described, the tibiales anticus and posticus and the peroneus longus play an important part in the maintenance of the arches of the foot.

(*b*) *During walking.*—In studying the movements of the foot (and of the whole lower limb) during walking it is necessary to commence with the military position of "attention," the trunk, thighs, and legs vertical, the heels together, the feet forming an angle of 45° with each other, the knees fully extended, and the feet at right angles to the legs; of course in addition the shoes should be removed. Place yourself in this position, and suppose that you wish to set off with the left foot.

By a slight inclination of the trunk and pelvis to the right you will put a little extra weight on the right leg, which remains vertical; by simultaneous extension of the ankle and flexion of the knee you will lift the left heel off the ground until the toes, though

still in contact with it, are transmitting no weight. At this moment commences the stage of purely right-sided weight-bearing; during this stage there devolves on the gluteus medius muscle the important rôle of keeping the pelvis tilted to the right, so overcoming the action of the body weight and preventing the trunk from falling to the left.

This heavily-loaded right lower limb acting as a pivot, the left leg is swung forwards by combined flexion of the hip and extension of the knee; at the same time the whole left limb is shortened by elevation of the foot into a position at right angles to the leg; whilst the pelvis is lowered and, turning a little on its pivot toward the right, is at the same time carried forwards by complete extension of the right lower limb, which for the moment comes to slope downwards and backwards. In the meantime the left heel has come into contact with the ground; at this stage the left leg slopes obliquely downwards and forwards in a direction the exact opposite of that of the right leg, so that the distance between the two feet at this stage of bilateral support of the body weight represents the length of the pace.

The left foot, at first flexed at the ankle joint with the heel alone in contact with the ground, becomes in turn extended into a position of slight equinus with the sole now flat on the ground, then flexed to the right-angled position, and finally to an acute angle. At the same time the right limb, by an active and not by a mere passive or pendulum movement, is lifted from the ground and swung forwards.

Hence in order to be correctly and normally carried out, walking demands a range of flexion of the ankle joint to a point a little less than the right angle and of

extension to almost 135°, a range of from 25 to 30 degrees of flexion at the knee joint, and a range of about 25 to 30 degrees of both flexion and extension at the hip joint. Under these circumstances only will the heel first come into contact with the ground, then the whole sole, and finally the toes alone.

When, however, a boot or shoe with a heel is worn the foot is forced to assume a position of equinus whenever the sole of the boot is flat on the ground. The usual height of the heel is from 2 to $2\frac{1}{2}$ centimetres; hence during the stage of bilateral body weight bearing the knee, without being actually flexed, has not the normal tendency to become hyperextended. In proportion as the height of the heel is increased the knee will during this stage become more and more flexed, the range of movement of the ankle joint will progressively diminish until a point is reached of complete suppression of all movement of the foot on the leg; this is what occurs with the fashionable shoe with the Louis XV heel, in which the foot remains in a position of fixed equinus.

C. *Ankylosis of the Ankle Joint*

1. *Ankylosis at a right angle.*—When the ankle joint is ankylosed in this position the body weight during standing is transmitted through the foot quite normally.

In walking, the normal antero-posterior roll of the foot on the ground becomes impossible; so too is the flexion of the ankle joint that normally accompanies flexion of the hip and extension of the knee during the period of swinging forward of the limb.

Hence in order to raise the foot from the ground and

carry it forward it becomes necessary to exaggerate the tendency towards rotation of the pelvis on the sound limb; this again necessitates walking with the knee fully extended, as on a peg leg.

In time this becomes a mode of progression involving but little extra fatigue, and one, moreover, that need not be at all ungraceful, especially if a certain amount of elevation of the heel of the boot on the affected side be allowed. Where ankylosis has taken place, with a slightly acute angle between the foot and the leg, *i.e.* in a position of slight flexion of the ankle joint, a considerable improvement in the powers of walking will be noticed.

This right-angled or acute-angled position of ankylosis, then, is from the functional point of view distinctly favourable.

2. *Ankylosis of the ankle joint in a position of equinus.*—Ankylosis in the equinus position is, on the other hand, distinctly unfavourable.

In standing, the weight of the body is transmitted to the ground through the metatarso-phalangeal joints which become hyper-extended, the heel remains elevated from the ground, the knee and hip flexed to compensate for the lengthening of the limb.

In walking, too, the foot cannot be lifted off the ground without an exaggeration of the normal lateral obliquity of the pelvis and of the flexion of the knee and hip joints that is proportional to the degree of the equinus.

The foot, having thus been brought forward most ungracefully, strikes the ground, not heel first but toes first.

If the toes only can be brought into contact with the ground—which is the case in severe equinus—

the flexion of the knee, and hence also of the hip, has to persist to compensate for the obvious lengthening of the limb.

Where, however, in cases of but moderate equinus, the patient does fall back on the heel, and so succeeds in getting the sole flat on the ground, flexion of the ankle joint being impossible, there results during this stage an upward and backward obliquity of the leg; this in turn implies a hyper-extension of the knee joint just at the very time when the whole weight of the body is taken on this limb alone. This in time produces a permanent stretching of the posterior ligaments of this joint, with development of genu recurvatum and lateral mobility, so that the stability of the limb becomes seriously impaired.

Such serious and disabling sequelæ will not occur, however, (1) when the equinus is compensatory to shortening of the limb, *e.g.* from fracture of the leg or thigh, and (2) when the equinus is not greater than that given to the sound foot by the ordinary thickness of the heel of the boot.

In such cases the gait becomes merely not quite so good as that obtaining in ankylosis at the right angle.

There exists, however, a definite limit beyond which further shortening is certainly not beneficial.

1. Despite the opinion of many of the so-called "orthopædists" who make surgical boots for cases of shortening from old hip disease, walking in a position of marked compensatory equinus is not to be recommended: the weight of the body is transmitted obliquely through the point of the foot, so that the toes become hyper-extended; indeed in extreme cases the weight is taken wholly by the great toe, which, compressed into the point of the boot, becomes

painful, and not infrequently develops an ingrowing toe-nail. Loss of all normal elasticity at the ankle joint adds further to the disability. In general the patient walks much better on an ordinary high boot with the sole flat, not sloping. Should the surgeon decide under these conditions to decrease the disability by operation, I am inclined to think that he would be right; but it is certainly wrong to conclude that during treatment of the fracture the foot should be allowed to become fixed in equinus.

2. In cases where there is no shortening of the limb, but where the degree of equinus is greater than that given to the other foot by the heel of an ordinary shoe, I have often been asked to prescribe a surgical boot with a raised heel. This, however, would necessitate standing and walking with an exaggerated flexion of the knee joint.

Where there exists but 1 to 2 centimetres of elevation of the heel, such a boot may quite well be given; indeed in cases where operative correction of the deformity is impossible such is really indispensable in order to avoid the development of genu recurvatum.

Any elevation of the heel greater than this is, however, bad; in such cases an operation is absolutely indicated—cuneiform tarsectomy followed by immobilisation in plaster in good position.

3. Ankylosis of the ankle joint in equino-varus is still more disabling than the former condition of ankylosis in pure equinus. In the standing position the body weight is transmitted through the anterior part of the outer border of the foot, and even in part through the anterior part of the dorsum. Hence during the weight-bearing stage of walking all stability of the limb is lacking; and where there is no

co-existent ankylosis of the mid-tarsal joint, walking simply results in a progressive exaggeration of the varus element of the deformity.

In such cases of fixed equino-varus no surgical boot or appliance can possibly be of any use; no support, whether of leather or of metal, is capable of resisting the inward twist of the foot that occurs during the period of unilateral weight support on the point of the deformed foot. Except as regards one particular, the mechanical condition is absolutely analogous to that of congenital talipes equino-varus. In the child, an adaptation that is impossible in the adult may and often does occur, resulting in a better though not in a very graceful mode of progression: the bones of the child's foot are so much more plastic, so much more easily moulded, that in time the anterior part of the foot actually comes to lie at a right angle to the posterior part, its plantar surface looking directly backwards. Under such conditions weight is transmitted through the heads of the astragalus and os calcis, and so through the dorsum of the foot, the patient walking as on two peg legs; the feet, however, still remain to a certain extent twisted inwards, so that an excessive rolling of the pelvis becomes necessary to avoid their catching on each other as the child walks. The occurrence of such a degree of adaptation at the mid-tarsal joint in the adult is quite out of the question.

In such cases the only possible treatment consists in resection of part or of the whole of the astragalus; because of the existence of the ankylosis this will not be a typical astragalectomy; it will rather be a form of cuneiform osteotomy carried out with mallet and chisel. After such an operation it is necessary to

guard against the development of a secondary varus deformity ; this will occur if the os calcis slips too far forward out of the tibio-fibular socket, so that the fore part of the foot is drawn inwards. It is advisable very often to resect in addition the anterior extremity of the os calcis.

On completion of the operation the limb should be immobilised in plaster for six weeks in a position of calcaneo-valgus.

4. The instinctive attitude of relief or repose adopted in inflammatory conditions of the joints of the foot is one of equinus, very often associated with a tendency to varus. In cases of wounds of or about the ankle joint, then, the greatest care should be taken to guard against the assumption or persistence of this position.

From the very beginning the patient should not be allowed to lie on the affected side, with his whole lower limb reposing on its outer side, the knee flexed and the foot dropped into equinus. The foot should be bandaged in such a way as to incline it into a position of calcaneo-valgus, and in this position the foot should be fixed as efficiently as possible in some form of skeleton or wire splint. Later, but as soon as is compatible with the condition of the wounds, and if necessary under an anæsthetic, the foot should be fixed in plaster in this position of calcaneo-valgus.

D. *Ankylosis of the Mid-tarsal and Sub-astragaloid Joints*

1. Ankylosis of these joints in the straight position of the foot, the long axis of its anterior part a continuation of that of the posterior, and the sole of the

foot in normal relation to the ground, results in no particular disability.

Under these conditions the long adductor and abductor muscles of the foot lose all such action and become merely direct flexors and extensors of the ankle joint, the normal range of movement of which is not in the least interfered with. Moreover, although during walking the occurrence of a slight amount of extension at the mid-tarsal joint during flexion of the ankle joint adds somewhat to the grace and ease of the movement, yet the absence of this is of no great practical importance.

2. The attitude instinctively adopted in osteo-arthritic lesions of this region is that of adduction and flexion—in other words, one of varus, with equinus of the front part of the foot. Especially where there has been any loss of bone substance in the neighbourhood of this joint does the tendency to this position of cavo-varus persist for many months, chiefly owing to the cicatricial retraction of the soft parts in the sole of the foot. Such a position is, of course, one of great functional disability. Hence in these cases it is of the utmost importance to see that the foot is kept firmly fixed in a position of calcaneo-valgus until such time as the synostosis has become complete and solid.

8. Ankylosis of the Knee Joint

The position of election in complete ankylosis is that of full extension.

With the knee fixed in this position there is no change in the standing attitude of the body.

The patient walks, however, as on a peg leg, lifting

the limb from the ground by tilting the pelvis and swinging it forwards by a slight movement of flexion of the hip combined with rotation of the pelvis around the sound limb. In the early days of their disability the patients walk with the whole limb externally rotated. Many never succeed in correcting this; but others, thanks to the remaining elasticity of the foot and of the hip, succeed in walking with hardly a limp, and are not more easily fatigued than a normal man.

The existence of up to 3 to 4 centimetres of shortening is decidedly favourable, as it tends to diminish the necessary range of lateral oscillation of the pelvis. This is important, for I have more than once been asked by a patient to order a high boot which would be far more of a nuisance than a benefit to him.

The occurrence of such shortening is fortunately frequent, for ankylosis of the knee joint is most commonly the result either of a resection of the joint or of a fractured femur.

In order to assure this position for ankylosis it is necessary to watch all cases of suppurative arthritis of the knee joint most carefully, for the naturally and instinctively assumed position is that of about 135° of extension, whilst, since the patient tends to lie on his affected side, this is usually complicated by some outward rotation of the tibia.

It should certainly be recorded, however, that among all the numerous cases of ankylosis of this joint that I have seen none has been in a really bad functional position. A few have been flexed 10 or 15 degrees, but this does not entail any great inconvenience. Hence it is obviously unnecessary for me to waste time here discussing the methods of splint-

ing or of immobilising the knee joint; these, it is quite evident, are sufficiently widely known already.

Whether performed primarily for extensive bony comminution, or secondarily for a badly draining suppurative arthritis, resection of the knee joint is most certainly a valuable operation; in practically all cases it results in ankylosis of the leg in a straight line. Even in cases where an extensive sacrifice of bone has been inevitable, and the saving of the limb has been accomplished at the expense of great shortening, the final result, when the patient has been fitted with a suitable boot, is considerably better than that of an amputated thigh; and late amputation can always be resorted to in the rare cases in which it appears useless to attempt to conserve the limb—for example, in cases complicated by an irreparable nerve injury or by persistent sinuses around the seat of excision.

The chief causes of failure of union are two:

1. A defect of operative technique—the performance of a hemi-resection of the joint, a failure to remove the articular ends of both bones, even although both may not have been involved in the fracture. A full resection of the joint should be carried out in all cases.

2. A defect in the after-treatment—too short an immobilisation of the limb. As a general rule, it may be laid down that the period of immobilisation in bed should be a full three months (longer where there has been a very extensive removal of bone); whilst on the patient being allowed up the limb should for a further three months be fixed in some form of walking splint, in a calliper or walking plaster splint.

Cases of incomplete ankylosis after compound

fracture of the lower half of the femur are quite common and deserve special mention. Often there is present some 10 to 15 degrees of flexion, which, however, is abruptly limited by a bony obstacle, the result of overgrowth and deformity of the condyles. On the other hand, full active extension is sometimes lost because of atrophy or loss of substance of the quadriceps muscle.

Ankylosis in flexion (I repeat, however, that I have met with no such case among our wounded) necessitates walking in compensatory equinus. Ankylosis in this disabling position should be treated by either cuneiform resection or by a low osteotomy of the femur. This latter procedure is suitable to two classes of cases: (1) cases in which the flexion does not exceed 25 to 30 degrees; (2) cases in which it is deemed wiser to restrict the field of operation to tissues that have not been the seat of a former infection.

Nothing should induce the surgeon to attempt the performance of an arthroplasty in a case of ankylosis in good position, nor should there ever be any attempt to retain or develop mobility in cases of primary resection.

9. Ankylosis of the Hip Joint

For two reasons I will deal with this lesion but briefly, despite its great importance: in the first place, because of the considerable mortality of infected wounds of the hip joint, it is of comparatively rare occurrence; in the second, its mechanical consequences, because of its association with hip disease, are familiar to all.

The position of election for ankylosis of the hip joint is, in the absence of all abnormal tilting of the pelvis, one in which the thigh is vertical, neither flexed nor extended, neither adducted nor abducted. Such a position is of course compatible with sitting with the body normally erect only when the sound buttock alone rests on the corner of a high stool. In order to allow of the patient sitting on an ordinary chair the body has to be flexed and inclined to the sound side. Standing is not at all interfered with, and the patient can walk far without fatigue, almost as well as in ankylosis of the knee joint. Walking is carried out, however, by an amount of lateral oscillation and rotation of the pelvis proportional to the general agility of the patient.

The instinctive attitude of relief adopted is during the earlier stages one of flexion, abduction, and external rotation; during the later, one of flexion, adduction, and internal rotation. On the adoption of such a position, when the pelvis is straight, the foot, hanging down at the end of the flexed leg, falls far short of the ground—enormous apparent shortening exists.

This is compensated for by an inclination and rotation of the pelvis, so that the leg is brought into a line parallel to that of the other, and the foot into contact with the ground.

Flexion is corrected by rotation of the pelvis forwards on its transverse axis; in order to maintain the balance the trunk is thrown backwards, and a lumbar lordosis results.

Abduction is corrected by a lowering of the pelvis on the affected side; in this way results a compensatory scoliosis convex to this side. The correction of

outward rotation is effected by a rotation from behind forwards of the pelvis on the sound limb, whence results a compensatory reverse rotation or torsion of the trunk.

Adduction is corrected by an elevation of the pelvis on the affected side, whence results a compensatory scoliosis convex to the sound side. Internal rotation is made up for by rotation of the pelvis backwards on the sound limb, which produces a rotation or torsion of the trunk in the opposite direction.

Such positions of deformity are of quite frequent occurrence, and interfere most seriously with walking, and even with standing in anything like an erect position. The method of choice for their treatment is sub-trochanteric osteotomy. In default of this the surgeon has to fall back on correcting the apparent shortening by means of a high boot, the sole of which should slope so as to give to the foot a position of slight equinus. Such is the palliative treatment that I am at present prescribing in the case of the wounded, in whom osteotomy of a femur that has once been infected should be postponed as long a time as possible. I have indeed performed one such osteotomy, not indeed for ankylosis, but for a sub-trochanteric fracture mal-united with considerable angulation—a condition that of course has mechanical consequences identical with those of ankylosis. The final result in this case was excellent, but was obtained at the expense of a serious recrudescence of osteomyelitis.

Apart from certain very special cases of ankylosis of the hip joint, surgeons are for the most part agreed in condemning all attempts at restoration of mobility by the performance of an arthroplasty.

Moreover, the many cases of resection of the hip joint that I have seen have ended either in ankylosis that is practically complete, or else in the formation of a pseudo-arthrosis that required a supporting apparatus taking the body weight from the tuber ischii similar to that for non-union of the femur, although acting under much more favourable conditions than that. If one considers that in these cases the resection, primary or early secondary, has succeeded both in saving the life of the patient and also in avoiding the necessity for that terrible mutilation, disarticulation through the hip joint, then surely all will agree that it is a most valuable and excellent operation.

CHAPTER II

STIFF JOINTS: FALSE ANKYLOSIS

Stiff joints, in contradistinction to ankylosed joints, should be regarded as including all those cases in which the limitation of joint movement—be it slight or severe—responds to one or more of the various forms of physiotherapy, even although in a certain number some accessory surgical treatment may have to be resorted to. Such a classification is based on purely clinical and therapeutic considerations, not at all on etiological or pathological conditions; it is on that account, however, a classification of the greatest practical importance, since it forces recognition of the fact that in these cases if treatment be commenced in time and prescribed with care and judgment, disability can be prevented, or if not wholly, at least in large part, cured.

These cases, then, are grouped together on grounds of clinical resemblance; in point of fact it would be quite impossible to formulate any scientifically exact and exhaustive definition of etiological factors and pathological conditions that would cover all the cases of this group. Certainly for the most part these are more extra-articular than intra-articular; but it would be wrong to generalise too widely as regards this point.

1. General Consideration of Pathology and Clinical Characteristics

(*a*) *Lesions.*—As far as can be gathered from the study of a few chance autopsies and amputations, and from observations made during the performance of certain orthopædic operations, the lesions are in the main extra-articular, in the sense that their first most striking characteristic is the absence of any form of union, even fibrous, between the articular surfaces, and that, in the second place, such slight changes in the articular cartilage as exist in the form of irregularities, roughnesses, and vascularisation are altogether secondary, both in time and in importance; indeed, in most cases they too are for very long conspicuous by their absence.

The chief lesion consists of an induration, a thickening, an increased vascularity and retraction of all the fibrous and connective-tissue elements of the affected region—of the synovial membrane and the joint capsule, of the ligaments, tendons, and tendon sheaths, of the intermuscular and subcutaneous planes of connective tissue with the bursæ they contain. The part played in the lesion by each of these tissues varies in different cases with the anatomical conditions of the affected region; for example, in the case of the shoulder joint the chief lesion seems to consist of a peri-arthritis with obliteration of the sub-deltoid serous bursa; in the case of the finger joints, of adhesions within the tendon sheaths. The serous lining of bursæ and of synovial membranes lose their sheen and smoothness, and their surfaces come to adhere together; all elasticity and suppleness disappear from the layers or planes of the connective

tissue, which thus comes to form an unyielding cylinder of hard retracted tissue surrounding the bone so as effectually to interfere with the movement of the joint. The skin and subcutaneous tissue also play their part in the process, become thinner, tougher, and more fibrous. Thus the whole of the lesion affects merely or chiefly the extra-articular tissues; the interior of the joint remains normal or almost normal, so that the full range of the articular movement is capable of being restored when and if these extra-articular tissues become again soft and yielding.

A further and most important element in the disability, however, consists in the atrophy and paresis of the muscles controlling the joint; the occurrence of this is to be constantly noted in civil surgery; whether of direct or reflex origin, such muscular lesions are equally constant and far more serious in the case of war wounds. I will, however, deal with these in a separate chapter.

As soon as the limit of the actual range of voluntary movement is reached, the least attempt to increase this range by passive forcing of the joint becomes excessively painful. So, too, the mere exercise of tension on one of the bony levers of a completely stiff joint is productive of great pain, and that although not the slightest passive movement has been induced. Moreover, the very occurrence of this pain often constitutes an important clinical point in differentiating between mere stiffness, however complete, and true ankylosis.

In addition, the pain thus produced possesses very special characteristics of its own, of very great practical significance and importance; although intense, it

is of short duration, it ceases as soon as the tension on the retracted tissues is relaxed, even in some cases dies away before this, so that it may be said that the patient and his tissues very rapidly become accustomed to the new joint position. Especially in cases where the affected region has formerly been the seat of inflammation is the observance of such characteristics of the very greatest practical importance to the clinician; for as long as this inflammation, although latent, is still in existence, such passive mobilisation of the joint will result too in pain, but in pain that persists in a considerable degree and for a variable time after relaxation of the tension of the joint. Hence as a general rule the duration of the pain, not its intensity, may be relied upon to give accurate information as to whether, the inflammation having long since subsided altogether, the condition is clinically one of mere joint stiffness that should be treated as such, or whether the causal arthritis, latent though it may be, is still in existence—in which case rest and not mobilisation should still be regarded as the treatment indicated.

(*b*) *Clinical types.*—It will be quite unnecessary after what I have said in the preceding chapter on ankylosis to insist further on the important distinction between joints that are stiff in good position and those that are stiff in bad, apart altogether from whether the stiffness be complete or not.

Very often the stiffness is incomplete; there exists but partial limitation—of greater or less extent—of the range of movement in one or more directions; for example, in the case of the shoulder joint, extension with adduction and internal rotation is usually more limited than flexion; in the hip, abduction with

external rotation more than adduction with internal rotation. This means, of course, that the tissue retraction is more marked on the side of the joint opposite to that of the limitation of joint movement.

Joint stiffness that is literally and absolutely complete is of rare occurrence. In nearly all cases it will be found possible by traction on the bony levers, if not to effect a certain slight amount of passive movement, at any rate to elicit a certain feeling of elasticity in the joint; of course such tension on the joint is inevitably accompanied by pain. This, then, serves to distinguish true ankylosis—at any rate bony, usually too firm fibrous ankylosis—from mere joint stiffness, no matter how complete this latter may appear. Usually, however, such slight amount of movement cannot be executed voluntarily; as far as active movement is concerned the loss is absolute, and in this sense cases of clinically complete stiffness are not rare.

This subdivision of cases into those of complete and those of incomplete stiffness corresponds almost exactly with the classification into cases of slight and of severe degrees of stiffness that we shall adopt when discussing the question of treatment.

(*c*) *General etiology.*—Joint stiffness may occur under two different sets of conditions; these although at first sight very different are yet in reality very closely related to each other: (1) as a sequel to a pathological joint condition, whether traumatic or inflammatory; (2) as a sequel to ill-advised immobilisation of a perfectly sound joint.

Let us glance first at the various primary pathological joint conditions that may result in stiffness

of, for example, the knee joint. This joint may become stiff after some aseptic trauma followed by an effusion of blood into the joint, or after a fracture of the patella that has been wired; following a trauma that in all probability was aseptic, *e.g.* a penetration of the joint treated by arthrotomy and immediate suture; following an obscure, possibly rheumatic, hydrarthrosis; following a non-suppurative infection, *e.g.* a gonococcal arthritis; sometimes even as a result of a mild suppurative arthritis that after treatment by arthrotomy has not ended in ankylosis. In a similar manner the commoner causes of stiffness could be reviewed in the case of each individual joint; each would be found to possess its own etiological peculiarities, some perfectly explicable, others obscure. This would naturally lead on to a discussion as to the reason why, for example, stiffness so often and readily occurs after a dislocation or even a mere contusion of the shoulder joint, or from a sprain of the knee, but so rarely follows a sprain of the ankle joint or a dislocation of the hip.

Under certain definite mechanical conditions absolutely identical lesions—quite as serious in their effects—can, however, be induced in perfectly intact normal joints; and if we wish thoroughly to understand the pathogeny and the prophylaxis of such joint stiffness, it is of the utmost importance that we should pay special attention to the study of those conditions that are responsible for so much joint disability; always bearing clearly in mind, however, how trauma and inflammation themselves have so constant a tendency to end in joint stiffness.

2. Pathogeny: Preventive Treatment

(*a*) *Pathogeny.*—The first point to remember is this, that if kept fixed in one permanent position any joint will in time become stiff, although the actual period of immobilisation necessary for this, and the degree of the resultant stiffness, will be found to vary not only in the case of the different joints of the body, but in the same joint with the presence or absence of certain factors whose influence it is important we should now study.

1. In the first place—age; briefly put, the older the patient the more readily do the joints stiffen; this is a fact not only well known, but absolutely true. Connected with this factor of age, too, is that of a constitutional tendency to that obscure disease, rheumatism; the joints of a "rheumatic" person, although they show no previous signs of a chronic "dry" arthritis, are nevertheless especially liable to become stiff after quite a relatively short period of immobility. In a child a sound joint that has been kept for many months in one position will often in a few weeks regain its normal range of movement, and that spontaneously, merely with use and without the help of any special treatment. A good example of this is the rapid recovery of movement in a knee joint that has for long months been immobilised in plaster with a tuberculous hip. Compare with this the condition of stiffness into which an adult's knee joint gets when kept extended merely for a few weeks, as, for instance, during the treatment of a fractured femur. This factor of age is of the greatest importance, for a considerable proportion of our wounded in this war are well over thirty.

2. It is commonly held that small, closely set joints like those of the fingers have a special liability towards stiffness. On the other hand, however, peri-arthritis with stiffness of the shoulder joint can hardly be considered as of rare occurrence. I believe that the apparent predisposition of such and such a joint to stiffness depends on (1) its relation to certain special peri-articular anatomical structures, *e.g.* serous bursæ and tendon sheaths; (2) the extent to which it becomes necessary for the patient, when the joint is freed from all external restraint, to make use of it in the actions of everyday life; (3) whether the primary position of the joint at this moment of release is favourable or not to the performance of these acts. When this position is favourable the patient will soon learn to make use of the joint; when unfavourable, he will almost inevitably find some way of dispensing with its use, and so the stiffness will not only remain, but grow progressively worse. In addition, it is precisely this attitude of functional disability that specially predisposes to the occurrence of stiffness; the rationale of this I will now explain.

3. The position in which the joint is immobilised is the most important factor in the production of stiffness.

When dealing with the subject of ankylosis I have indicated to the best of my ability the position of election in connection with each of the most important joints of the limbs; and also in addition the instinctive attitude of repose or relief adopted during inflammation, which, unless precautions are taken, becomes the position of ankylosis—a position almost invariably unfavourable to the future function of the limb. We

must now determine what the instinctive assumption of this position really means and why it so specially predisposes to the occurrence of stiffness.

By injecting fluid into joints under pressure by means of a needle passed through one of the epiphyses, Bonnet of Lyons has shown that, at the moment when any further injection would result in bursting the joint capsule, the joint becomes absolutely fixed and rigid in a certain definite position, constant for each joint. This position then represents the maximum capacity of the joint, in other words, the maximum distension of the joint capsule, a degree of distension that would be quite impossible to obtain by any but a very slow and gradual distending force. If now, without changing the position of the joint, the fluid be evacuated, this condition of extreme distension of the capsule will give way to one of extreme relaxation; and as previously some of the fluid had penetrated between the bone surfaces, these will now be found to remain some little distance apart. Now it is a well-known fact that certain joint positions that are not well adapted to the functional requirements of the limb are just those not particularly remarkable for their mechanical stability; for example, lateral mobility of the elbow and knee joints is quite marked in the position of 135 degrees of extension, whilst with full extension of the knee joint and with flexion of the elbow to a right angle no such lateral mobility will be found to exist.

Actual cases of extreme distension of the capsule of the knee joint, as, for example, by hæmorrhage, will very frequently be found lying on their affected side, the knee fixed and rigidly immobilised in this position of 135 degrees of extension. It may be argued that

in cases of the most abundant effusion ever met with the knee often remains quite as freely movable in all directions as on the sound side. Such extreme effusion, however, always takes place gradually and with no great violence, for ligaments, being composed of fibrous tissue, will always tear rather than be violently stretched, but under the action of a persistent gradual distending force they will yield readily enough. Certainly a sudden acute effusion as from a hæmorrhage does not exert a force comparable to that realisable by artificial injection with a syringe —a fact that serves to explain why the position assumed clinically by the joint never quite coincides with the experimentally produced standard position of Bonnet.

In acute arthritis, moreover, the effusion is never quite so abundant nor takes place so suddenly as in a hæmorrhage ; but the final result is much the same ; the patient, in order to relieve the pain, instinctively relaxes the tissues as far as possible so as to avoid all unnecessary increase of tension or pressure ; consequently the joint is held immobile in the position of its maximum capacity, a position that at least approximates to that produced by experimental injection.

Now let us inquire how it is that this position, always as regards the future function of the limb a mal-position, in itself predisposes to the occurrence of stiffness, of future limitation of the normal range of movement of the joint.

Distended, and hence destined on the subsidence of the effusion to become relaxed to their utmost, the ligaments in relation to the joint, little by little shorten, adapt themselves to the new distance that

separates their points of attachment; so that if this same position of the joint be maintained for some time it will soon become a permanent one, the relative position of the bony levers to each other becoming, through the retraction of the ligaments, a fixed one.

Where, on the contrary, the joint is immobilised in a functionally good position, the ligaments can undergo shortening only on one side of the joint; on the opposite side their retraction is prevented by their being kept on the stretch by the immobilising force. Thus in extension of the knee joint as in flexion of the ankle, the posterior ligaments remain taut and cannot retract; the danger in the case of these two joints being of course the occurrence of a contrary state of affairs, viz. the adoption of the positions of flexion of the knee and of extension of the foot both of which would allow of permanent retraction of their respective posterior soft parts.

4. So far we have been dealing with the conditions predisposing to the development of stiffness in previously sound and healthy joints. It is obvious, however, that, other things being equal, this predisposition will be greatly increased in cases where certain various pathological lesions exist in or around the joint:

(*a*) Where although the joint itself remain intact there exist inflammatory changes or œdema in the surrounding soft parts. An example of this is the stiffness that occurs so rapidly in all the finger joints with a cellulitis of the palm of the hand.

(*b*) Where there has occurred some definite lesion, no matter how superficial, of the joint itself, either in the nature of a sprain or contusion, especially where

the latter has been associated with an effusion of blood into the joint (knee), or around it (shoulder), or else of a slight actual arthritis, aseptic or even mildly infective.

(*b*) *Preventive treatment.*—I have already sufficiently well indicated in the case of each joint the position of election for immobilisation.

It should also be now quite clear how important it is that the period of immobility should always, and especially in the case of healthy joints, be as short as possible.

1. *Immobilisation and mobilisation in the case of sound joints.*—It is impossible absolutely to immobolise a fracture without including in the plaster or splints its two adjacent joints, the one above and the one below the seat of the fracture. Now, although the opposite practice of dispensing with such joint fixation has its champions and adherents, yet the necessity for it is absolute, at any rate during the transport of compound fractures to the base; the earlier the patient is moved the more essential this becomes, the more efficiently should it be carried out. Such complete immobilisation is the best preventive of the spread of the infective inflammatory process, and the best means of avoiding such secondary complications as the laceration of large vessels by spicules or sharp fragments of bone; hence the practice of evacuating all compound fractures in extensive plasters, with windows cut for dressing the wounds, or else the various segments of the plaster united by bridges and bars of metal. These plasters include the whole of the wounded limb; in the case of a fractured humerus, for example, the shoulder, the flexed elbow, and the wrist are all included and

immobilised at once, immediately after the performance of the primary operation at the front.

But as soon as possible this extensive plaster should be removed; such absolute immobilisation of the seat of the fracture is not at all necessary for the attainment of union (because of this some surgeons have wrongly concluded that there is no need for the immobilisation of fractures at all). The fractured bone should be fixed in simple splints that allow complete or at least partial freedom of movement to the adjacent joints. This the walking splint devised by Delbet for fracture of the leg allows to the knee joint and to the joints of the foot; in fracture of the bones of the forearm a well-fitting and perfectly efficient gutter splint need fix neither the elbow nor the fingers; for fractures of the humerus and femur the continuous extension apparatus introduced by Delbet or one of its numerous war modifications is practically ideal.

Similar treatment should be adopted as regards the mobilisation of the rest of the limb in cases of suppurative arthritis of one joint; as soon as the acute inflammatory complications have subsided, the suppuration has moderated and the injured joint has become free from pain and all peri-articular swelling disappeared, movement of the neighbouring intact joints should be freed from all restraint. This presents quite a simple problem to a surgeon who knows how to apply plasters, whether in bandage or in splint form.

In the case of mere flesh wounds the reasons for setting joints free as early as possible are still more cogent. How often does one see not only in military but in civil cases the whole hand bandaged for a

lesion limited to one or two fingers. The extent and size of such a dressing is bad, in that it magnifies the importance of the wound in the eyes of both the dresser and the patient; this apart altogether from the question of the financial results of such extravagant use of cotton-wool, gauze, and bandages: the immediate expense of the material and the extra and needless and quite avoidable expense of the additional pension that will become necessary on account of the stiffness of joints and the wasting of muscles that are going on beneath the cramping and voluminous mass of the dressings. Let the dressing, then, always be light, let its size bear a reasonable relation to the extent of the wound, let the quantity of the cotton-wool be merely sufficient to absorb the discharge, for it should always be remembered that free entrance of air to the wound can never have any but a beneficial effect. There can, too, be nothing worse than the constant application of wet dressings to the hand or the foot.

2. *The immobilisation of injured joints.*—Having said thus much concerning the treatment of joints not actually involved in but merely contiguous to wounds, I must now deal with the question—often one most difficult to decide—as to when a joint that has been actually involved in the lesion should be immobilised, when free movement and active use should be allowed to it.

In the case of a contusion or a sprain immobilisation in plaster is never called for; all that is necessary is tight bandaging over a layer of cotton-wool so as to exercise firm and equable pressure; whilst in order to prevent wasting and atrophy of the limb, immediate care and attention should be focussed on

the condition of the muscles; where the joint is filled with blood—as is usual in the case of the knee joint—this should be aspirated; and from the outset the patient should be encouraged to commence gentle, active movement. I am not at all sure, however, that the modern practice of allowing the patient to walk at once is wise. Such is no doubt all very well in cases where no actual laceration of ligaments has taken place, but as in most cases such laceration has occurred, too early walking (I mean before the eighth or tenth day) without a bandage or splint to keep the knee extended involves, in my opinion, a serious risk of permanent laxity of the ligaments with a consequent development of excessive lateral mobility. Examples of this sequence of events are not rarely seen at the Grand Palais.

As to cases of actual joint inflammation, whether spontaneous in origin or the mild non-suppurative form that remains after arthrotomy for an aseptic trauma, it becomes a matter of clinical experience and judgment to decide when the pain provoked by pressure or movement has become sufficiently slight, when all effusion has disappeared from the joint, to determine when resumption of the normal function of the joint may be cautiously commenced. In such cases it is the duration of the pain, and not its intensity —this is always at first extreme—that is to be taken into account as of such very great practical importance.

3. *The resumption of normal function.*—It is not sufficient, however, to free the joint from all external restrictions: it is necessary that the patient should make full active use of it. Now he always has an instinctive tendency in order to avoid pain to keep

himself from using the limb, and this even where the wound has been but a slight one of the soft parts only. The surgeon's attention should be directed to this matter, both during the period of the patient's confinement to bed and when he begins to get up.

In many cases of wounds of the upper limb the tendency of the patient while lying in bed is to keep the limb alongside the body, the elbow in full extension (a deplorable position), and the forearm in pronation (which is hardly less deplorable), and the wrist and fingers either fully extended or semi-flexed ; in other cases, to keep the arm across the body with the elbow more or less flexed ; in this position certainly the degree of the pronation is much less, but inevitably the wrist falls into the bad functional position of flexion.

As regards the lower limb, whether the patient lie in bed on his back with the knee fully extended or on the affected side with the knee flexed, the foot invariably drops into a position of equinus with more or less of varus, and this in time becomes associated with the development of clawing or hyper-extension of the toes (a deplorably bad functional position); this position results as much from the weight of the foot and of the bed-clothes as from the weak and relaxed state of the muscles of the leg. With the patient occupying either of these positions the wearing of a right-angled bed shoe or of a back splint is most important, for such gives vertical support to the sole, and also serves to keep the weight of the bed-clothes off the foot.

In addition, in both the upper and lower limbs it is most necessary from the outset to adopt the performance of daily movement of the fingers or toes, of

the wrist or of the ankle; such may be carried out passively and through a gradually increasing range every day whilst the patient is being washed or his wound dressed. Very soon, however, should such passive movement be supplemented and in time replaced by corresponding active movement, should the patient begin to exercise his fingers by grasping a successively smaller and smaller object (a ball of string, for example), should the foot be brought to the right-angled position as soon as it shows the least tendency to fall into equinus—this by means of a loop of bandage passed round the foot on which traction can be exerted either by the patient himself or by attachment to an elastic band, for example, an ordinary piece of rubber tubing.

Instead of such rational treatment, however, too often the patient is got out of bed—of which of course he is tired, and in which he is supposed to be losing strength—and given a sling or a pair of crutches! With what result we shall see.

(*a*) *The use of slings.*—The moment a patient wounded in the arm comes to sit up in bed he is nervous and anxious about his wounded limb, its weight causing him discomfort; indeed at this stage full extension of the elbow so that the limb can descend alongside the body is impossible. In too many cases the result of this is the adoption of a sling, too often a sling that envelops and supports, not simply the wrist and forearm, but the whole arm, fixes and immobilises it firmly to the front and side of the body, the elbow flexed to a right angle, the forearm in semi-pronation, the wrist flexed to somewhere near 45°, and the fingers either fully extended or semi-flexed. Fixed in this position the limb

remains not only throughout the day but during the night as well, so that shoulder, elbow, wrist, and fingers soon become definitely and obstinately stiff.

A sling that allows of full use of the fingers is better, provided that care is taken to assure daily movement of the fingers and hand; otherwise the wrist will become fixed in adduction and the fingers remain inert and extended.

What is necessary in these cases is a simple loop, which, pinned above to the sound shoulder, affords a temporary and occasional rest to the hand and arm; the patient can use it or not at will, and in removing and re-inserting his hand a certain amount of movement of the elbow and the shoulder is inevitable; little by little the patient becomes accustomed to and able to perform the common actions of every-day life, as, for example, eating and drinking. No doubt at first such movement will result in pain, but insist on their performance and you will succeed in avoiding serious stiffness.

Of course no one will expect in this way to avoid loss of function due to actual destruction, fibrosis, and retraction of muscle. But that is no reason why one should allow an additional and quite avoidable disability to become superimposed on what is inevitable and possibly irreparable. Such stiffness of joints as results from immobilisation in a sling is by no means invariably or necessarily the result of sepsis. One of the finest, or rather one of the worst examples of this type of stiffness that I have ever seen was that of a woman whose arm a charlatan (qualified nevertheless) had immobilised in a sling after vain attempts to reduce a dislocation of the shoulder joint; her nails were fluted; her fingers

stiff in extension; the skin of the hand thin and shiny; the wrist joint fixed at 45° of flexion and the elbow at 135° of extension; the disability could hardly be more complete, without taking into account the complete stiffness of the shoulder and the compression of the brachial plexus.

(*b*) *The use of crutches.*—Correspondingly similar considerations arise in the case of cripples who cannot walk except on crutches. Such patients get about with the foot dropped and with consequent compensatory flexion of the knee; whilst lying in bed—always of course on the affected side—the leg is kept in the same fixed position, the foot in equinus and the knee flexed. Many surgeons no doubt consider that such patients will be benefited by giving them crutches, by getting them up and about; as a matter of fact such treatment usually results in a more absolute fixation of the foot and in a more rapid development of stiffness than if the patient were strictly confined to bed and kept lying on his back. It is true that by getting up the patients get more general exercise and fresh air, but too often at the expense of a foot stiff in equinus and of stiff hyper-extended toes. The drag of the weight of the leg and foot is usually sufficient to prevent the knee joint from becoming quite stiff; stiffness of this joint was successfully accomplished, however, in one case that I have met, in which in order to relieve the patient of all effort the foot was slung by a band to the waist-belt.

Other surgeons go to the opposite extreme and refuse to allow their patients up until all their wounds are healed. This is of course logical, and in theory ideal; but its realisation involves difficulties that

are not compensated for by the benefits gained unless one can succeed in considerably shortening the ordinary period of healing. Before, however, any patient is allowed to walk his wounds should certainly be almost healed, and his joints, especially those of the foot and toes, supple and in good position, so that the sole can be brought into normal relation with the ground; even under these conditions the patient must be trained to make active use and to take active control of each of the joints of the injured limb. The ideal course would be to allow the patient to walk only when he is capable of so doing correctly and with the assistance merely of a stick. But of course one has to compromise and allow two sticks or a pair of crutches, but this should be done only on condition that they should be used solely to assist the limb in bearing the body weight, and on no account to relieve it of all active effort and use; walking on one leg and a pair of crutches should never be allowed. For example, there is no reason why a patient fitted with a walking apparatus for fracture of the leg or thighs should not be given crutches provided that his foot is normal; but there is every reason in the world why they should not be allowed in the case of a patient whose foot, no matter how slightly wounded, is fixed still in even the slightest degree of equinus.

3. Curative Treatment

Restoration of mobility in the case of stiff joints may be effected (*a*) by certain indirect methods, (*b*) by one direct specific method—movement itself.

(*a*) *Indirect methods.*—These I will do no more than enumerate. In the first place, massage is one of

the most important and one of the most effective—massage both of the peri-articular tissues, which thus become less œdematous, and massage of the muscles, which serves to prevent their atrophy either altogether or at least in great part; indeed in this latter respect I believe massage to be very greatly superior to electrical treatment. Frequently repeated voluntary contraction, even though purely static, of the muscles around an immobile joint is also a most valuable method of maintaining muscular tone and development and preventing atrophy.

Daily immersion in hot water (about 112° F.) is certainly of value in increasing the mobility and suppleness of a stiff joint; careful record should be kept of the range of movement possible when the limb is actually in the bath, especially as, when under water, the movement of the limb becomes easier in accordance with the principle of Archimedes. In place of such baths or alternating with them one may make use of the hot douche.

What are we to conclude concerning the therapeutic value of the addition to the hot water of sulphur or various mineral salts? The answer to this must remain for the present undecided. I believe that certain continuously active mud baths contain minerals the beneficial action of whose chemical and physical properties, although the exact nature of these remains obscure, cannot be denied. But in the case of the ordinary mineral baths it would seem that the addition of the chemical agents has but little therapeutic significance.

Each spa, of course, extols the virtues of its own particular waters; but as each is in turn described as the most "radioactive," their exact chemical

constitution would seem to be of no very great importance. The advantages to be derived from such spa treatment are probably due in part to the warm water and in part to these centres being well equipped for general physiotherapy.

I am not at all convinced, moreover, that either ionisation or radium therapy is of any special value whatever; certainly they are of no greater value than most of the numerous agents that we are being continually asked to accept as specifics.

(*b*) *The direct method.*—Movement is the great specific for stiff joints: when prescribed at the right moment, and regulated both as regards duration and force, it is a therapeutic agent of the greatest value.

The correct moment when mobilisation of a stiff joint, previously the seat of inflammation, should be commenced is that at which the pain induced by it, though often intense, does not persist after the movement has come to an end. In many cases the passive mobilisation of a stiff joint will be found to result in a recrudescence of the inflammation; such inflammation should be treated in the usual way, *i.e.* primarily by rest, all further movement for the time being interdicted. In other cases, however, the mobilisation should be repeated as frequently as possible and as is compatible with the character and duration of the pain. These rules apply equally to all the various methods of mobilisation that we have at our disposal.

Thus the movement may be active, executed by voluntary contraction of the muscles normally controlling the joint, or passive movement mechanically communicated to the joint by the patient himself, by an operator, or by means of a machine. Such passive movement will be either gentle and progressive

or sudden and forcible. The former method usually suffices where the degree of stiffness is but slight; after a short trial it is usually very easy to decide whether the case is going to yield to such daily gentle manipulation or not; in the latter case it is no use wasting time by persisting with it; in such cases, cases really of severe stiffness, forcible mobilisation should be resorted to at once. This distinction between slight and severe degrees of stiffness should not be construed as synonymous with that between stiffness of small and large joints. We will first study the treatment of the simpler cases—of joints stiff in good position; later, the correction of joints that have stiffened in mal-position.

1. **Joints Stiff in Good Position.**—In such the object of treatment is simply restoration of the normal range of movement.

(*a*) *The treatment of slight degrees of stiffness.*—In the case of slight degrees of stiffness the chief therapeutic agent should be active movement; no case should be treated by passive mobilisation alone; such should always be at least supplemented by active movement. In some cases such mobilisation may result in a more or less marked degree of reaction.

When a patient with a stiff joint—the result or not of an attack of arthritis—is first set free from splints, allowed to commence movement and active use of the limb, we have to depend to a great extent on the spontaneous progressive return of movement, effected both by voluntary or reflex muscular contraction and through the influence of such passive external forces as gravity, and the forcible and inevitable shocks and communicated movements of everyday life.

The mechanical conditions are different in the case of the two limbs; in the case of the upper its own weight constantly tends to straighten it out, but as soon as the patient puts his foot to the ground the body weight, acting in a reverse direction, from below upwards, has the opposite tendency. But in the case of both limbs it becomes necessary to supplement voluntary movement, always at first very slight in range and weak in strength, and constantly limited by fear of pain, by involuntary passive movement, which, being sudden and forcible, is always extremely painful. Such passive movement is alone capable of breaking and reclaiming new ground, ground that is subsequently gone over and retained by the ordinary active voluntary movements.

Such a sequence of events may result more or less accidentally by the occurrence of a certain amount of "false movement" during the ordinary routine of daily life, movement active or passive induced in the limb at a moment when the patient is least expecting it. In some slight cases the régime of the patient's ordinary work may be relied upon to induce sufficient movement to bring about a cure. But except in very slight cases it would be unwise to trust to this. In most cases the patient should be set to perform regular and methodical exercises, modified and suited to the needs of each particular case; and for this purpose he should be instructed how to make use of the ordinary articles of his home as agents of passive resistance.

Commencing with the upper limb, let me give some examples of this "home mechanotherapy."

In the case of the shoulder joint the range of its two most important movements—abduction and

internal rotation—can be very easily and simply increased; twenty-five years ago I gained for myself in the course of a week quite a small reputation at the expense of a bone-setter, who had reduced a dislocation of the shoulder (in which, by the way, a doctor had failed) but had made the mistake of immobilising the arm in a sling for a month, after which he did not know how to set to work to get rid of the stiffness, to regain for the patient the power of abduction of the arm.

The following would be my instructions to such a patient: Sit down parallel to a table and rest the point of your elbow on its edge and then gradually and slowly move your body further and further from the table, keeping, however, the elbow in position; in this way you will passively open up the angle between your side and your arm. This no doubt will cause you some pain; when you feel that you can bear no increase in this, do not move any further, but without actually increasing the angle between body and arm maintain this position for several seconds, keeping the arm and body tense; then without moving just relax the tension; finally commence to diminish the angle again, and so return to the original position; rest a few minutes, and then repeat the manœuvre, and so on.

Or stand in front of a mantelpiece, or a bookcase whose shelves will provide you with a choice of heights, and lean on your elbows in the attitude of a *beau ténébreux* of 1830, and as long as you maintain this position you will be executing, and that without anyone noticing it, exactly the same movement as in the last exercise.

You will easily understand that by making use of in

turn a higher and higher support, and by gradually increasing the distance between the bottom of the bookcase and your feet or chair, and so coming to bend your body more and more, you will be exerting a progressively greater pull and tension on the tissues of the armpit.

Again, it will be perfectly obvious to you that in the first exercise you can develop the range of forward movement of the arm simply by advancing your elbow further and further in front of you along the edge of the table and moving your body not directly outwards but outwards and backwards.

I must now explain to you that when you have succeeded in elevating your arm to form an angle of 45° with the body the great part of this is only apparent gain, is due to a rotation of the shoulder blade, and only a small part of it represents actual stretching of the adhesions round the joint. But do not on that account be discouraged, for neither you nor any one with special apparatus can efficiently fix this bone so that it will not rotate. Persevere now, but with a different exercise. Sit facing, but at some distance from, the table with your elbow resting on it and flexed and your brow resting in your hand, your face turned somewhat towards the affected arm, your whole attitude that of one lost in deep thought; then pass your other hand above your head, interlace the fingers of the two hands and pull at first gently, then more forcibly, and finally passionately; in time, in order to regain the last degrees of abduction and elevation of the arm, it will become necessary for you to shift your hand to the opposite side of the head, and in addition to incline your head itself well over to the sound side. And in

the course of this exercise as of all others proceed by first reaching the position of toleration of the maximum amount of pain, by maintaining and then relaxing this position, finally by returning to the original attitude and commencing afresh; in addition, always finish by giving a little extra force to the last movement.

In this exercise you have allowed the scapula to rotate to its utmost and have been exerting a direct pull on the shoulder joint itself.

You can test the range of internal rotation possible at this joint by attempting to assume the "Napoleonic attitude," the forearm being carried transversely across the small of the back. If, however, you cannot place it at once in this position, commence gradually. With the stiff limb hanging alongside the body, the thumb internal and the back of the hand facing forwards, pass the other hand behind the back and seize hold first of the thumb, then of the fingers, and finally of the outer border of the stiff limb, and gradually pull it until it comes to rest on the buttock. When this has been accomplished, begin to pull this hand up behind the back. This will result in an increase in the flexion of the elbow and in the internal rotation of the shoulder. For both these actions this position provides an excellent leverage.

Where you wish, however, merely to increase the range of elbow flexion, it is much simpler and easier to do so by supporting the forearm against, for example, the side of an armchair and then decreasing the angle between it and the arm by pushing with the whole weight of the body; as regards increasing extension, the mere weight of the arm is constantly acting in this direction, and this of course can easily be reinforced by lifting objects of different weight.

In order to increase the range of backward movement at the wrist joint, support the front of the fingers flat on a table, let the knuckle joints flex, and then push the forearm towards the table, or else with the palm of the hand flat on the table carry the point of the elbow directly forward towards the table; in a similar way the range of forward movement of the wrist can be effectively increased by forcing the back of the hand flat on the table.

Having thus at length described these methods of utilising ordinary articles of furniture as agents of passive resistance in the performance of exercises, I need not give any detailed account of how the sound limb can be constantly engaged in communicating passive movement to the elbow, the wrist, and the fingers. The general principle remains the same; the joint is stretched until it becomes too painful to proceed further, is held tense in this position for some little time, and then relaxed.

The joints of the lower limb can be exercised by weight-bearing, the agent of passive resistance being the ground; such exercises should be carried out strictly in the light of our knowledge of their normal movements during walking. (See page 271)

There can be no better exercise than walking for gaining in the required directions the necessary range of movement at each of the three large joints of the limb—the hip, the knee, and the ankle. At the same time it will not be necessary to insist on the patient's marching exactly in the military manner; at any rate at first a little relaxation of gait may be allowed him.

I have already sufficiently insisted, in the case of patients wounded in the leg, on the importance of

getting their joints supple and in good position before they commence to walk. The foot at any rate should reach the right angle, and be fixed neither in varus nor in valgus; normal walking, however, demands a degree of flexion of the ankle joint greater than that represented by the right-angled position; the foot must reach a point some 18 to 20 degrees beyond the right angle.

In order to gain these few extra degrees of flexion it is usually sufficient to explain to the patient how in walking he should see that at each step the heel is always lifted from the ground before the toes, that the knee is flexed and not held stiff in extension, and, finally, that the heel is brought again carefully into contact with the ground.

If such self-educative methods fail, an excellent exercise for increasing the range of flexion of the foot beyond the right angle consists in standing on the affected limb, the sole flat on the ground, and alternately flexing and extending the knee; under these circumstances flexion of the knee necessitates simultaneous flexion of the ankle, and the whole weight of the body, tending to close the angle between foot and leg, comes to be exerted on the retracted posterior muscles and ligaments of the ankle joint. Such an exercise can of course be repeated an infinite number of times during the day. Another simple exercise consists in standing on the sound limb and with the front part of the sole of the other foot pressing the flexed foot against a wall. Or the patient may be set to work a sewing-machine with his foot; this has the advantage that the exercise commences with the foot in the equinus position.

Riding a bicycle is also an excellent method of

increasing the range of flexion of the ankle joint if the saddle be mounted low for the patient, of increasing the range of extension of the knee and hip if it be mounted high. Where the patient cannot walk—where he can, it is a tedious form of exercise—a stationary bicycle can be very easily and cheaply installed.

I have thus indicated the general principles of treatment and illustrated a few of the elementary means of their application to the conditions of particular cases. Such methods can be modified and multiplied according to the ingenuity of the surgeon to suit the need of individual cases. A more widespread adoption of this "home mechanotherapy" would be the means of a great saving of valuable time among numerous cases of our wounded.

In specially equipped centres, however, these special movements can be carried out by means of graduated apparatus, in which the patient performs each action separately against elastic or weight resistance, so that during one "séance" the special curative actions can be performed over and over again, voluntarily by the patient but at the same time methodically and under skilled surveillance. Various are the models that have been designed and constructed; it is easy, for instance, to devise an apparatus by means of which one or more fingers can be set to work in a definite prescribed way. Such apparatus, however, can do good only when and if the patient participates willingly in the work; their use should never be allowed to degenerate into the repetition of a passive action a certain number of times once a day, in the intervals between which the patient does nothing, even perhaps falls back on the

comfort of his sling or crutches and all the habits of immobility that they represent.

As soon as the joint becomes capable of a certain range of active movement the best of all treatment consists in a resumption of manual work—a resumption at first of course but partial, in time as power and range of movement increase a resumption in full. "This is mechanotherapy ten hours a day," as one of my patients remarked to me. Since we have come to recognise that we were for long on the wrong track, all now are coming round to the view that manual work is of the very greatest benefit to the wounded—a view that during the early days of the war was not at all received with favour. In this connection, re-educative works have been most valuable; re-education in town trades has been facilitated; the centres for education in agricultural work have been the means of converting many men formerly merely unskilled day labourers into skilled agricultural workers.

In the great majority of cases the daily use of the hands during work is of infinitely greater curative value than any amount of treatment by such purely passive agents as I have now to describe.

All passive movement—movement communicated to the joint by some external agent—should be regulated on the same general principle, the limit of movement marked by the commencement of pain should be reached, and the tension maintained for some seconds so as to stretch the retracted and shortened ligaments; especially in those directions that are to prove most useful and against those ligaments considered most resistant should such passive movements be carried out.

Manual mobilisation by a skilful operator is by far the best method of executing these passive movements, far better than by any machine; especially is this manual method valuable when combined with such aids to muscle development and training as massage and resisted exercises. In resisted exercises particularly can the amount of muscular work performed be better graduated than when the movement is executed against the force of a mere lifeless spring or elastic band; such exercises have the additional advantage over mechanical methods that the operator knows at once whether the patient is putting his heart into the work or is merely performing it perfunctorily. But good operators, skilful and intelligent, are not common, and there are many hundreds of wounded to treat; their number renders such individual treatment in all cases impossible.

Hence we have to fall back on mobilisation by mechanical means. The first types of machines were invented a long time ago, *e.g.* the old-fashioned machines of Louvrier, in which the two levers of the joints were embraced by two cuffs that were united by a hinge and a pulley arrangement allowed the patient or an operator alternately to exert and to relax tension on the joint. This type has been successfully modified to include the principle of continuous elastic traction, whether by coiled springs or by bands of rubber tubing, etc. Since the war P. Robin has designed a series of very ingenious apparatus which, though I am sure he is wrong in regarding them as working appliances, yet seem to me to be admirably suited for therapeutic purposes.

The ordinary type of apparatus which nowadays is in such demand in certain "institutes of mechano-

therapy" is, in my opinion, far inferior to those I have just mentioned. In this type of machine the upper lever of the limb being immobilised, the lower fixed in a cuff is worked backwards and forwards in a definite direction by means of an electric motor; such a method fails to realise the important principle I have so often insisted on—the steady maintenance of that position that corresponds to the limit of toleration of pain by the patient. In addition, all voluntary effort is entirely eliminated, and the patient has thus less direct and attentive interest in the movement than has a beggar in that of his barrel-organ. With no effect on tight adhesions such apparatus is equally useless after such adhesions have been broken down, and so is very greatly inferior to carefully regulated gymnastic exercises.

(*b*) *The treatment of severe degrees of joint stiffness.*—In some cases all these means fail; either they can create no such slight range of movement as may act as a starting-point for further gain, or else after a certain amount of improvement a point is reached beyond which progress becomes stationary. In all such cases there is no use in persisting with these methods; the way should be prepared for them by a preliminary forcible mobilisation carried out at one sitting. Such—it must be understood—will never by itself result in cure; what one aims at by forcible mobilisation is merely the conversion of a case of severe stiffness into one of slight, which must then be treated on the lines we have just laid down.

Special attention should be paid to the correct technique of forcible mobilisation.

After steadying the upper segment of the limb the surgeon should always commence by forcing the lower

segment in the direction that offers him the better leverage; this in the case of the knee and elbow joints means an increase in the degree of flexion. A slow, gradual, and steady force being exerted on this free segment of the limb, the adhesions will be felt to crack and give way at first slowly, but soon more quickly and easily. A series of alternate movements in opposite directions should now be carried out; each successive movement should carry the joint a little further in its direction than the preceding one; in the case of ball-and-socket joints the performance of circumduction should not be forgotten, and the surgeon should not desist until the full normal range of each movement has been realised.

If one judges by the appearance of patients in whom by a trick of the thumb we have suddenly flexed or extended a stiff finger or toe, forcible mobilisation is an extremely painful operation. Hence it is necessary to give an anæsthetic—chloroform or ether in the case of one of the larger joints where the manipulation will certainly take some time, ethyl chloride for the smaller joints where the operation will be of but short duration.

I have never been able to see any advantage in using special apparatus for forcible manipulation of joints.

When the operation is completed the joint should be fixed in good position and lightly but firmly bandaged for several days; the joint region swollen and bruised will be very painful, but slight active and passive movement should be commenced at once, later the full treatment instituted as for cases of slight degree of stiffness.

2. The Treatment of Joints that are Stiff in Mal-position.—Cases of stiffness with slight deviation from the

position of election hardly need to be specially considered; they usually yield to treatment on the lines laid down for cases of slight stiffness in good position, although perhaps rather more than usual importance should be attributed to the efficient performance of the corrective exercises. Where the deviation is one of rather greater degree the surgeon will have to have recourse to one of the methods of elastic traction already described.

The two chief genuinely surgical methods that have to be relied on in all cases that are not amenable to these milder forms of treatment are (1) gradual correction in stages and (2) forcible correction.

Gradual correction in stages by a succession of plasters, a classical method in orthopædic surgery, consists in obtaining at each sitting as much correction as possible, and in maintaining this by manual pressure or elastic traction until the limb is immobilised in plaster. At the end of a fortnight the retracted elements will be found to have yielded somewhat, so that a further gain becomes possible. I will not enter into details of the technique of this method, because I have never had occasion to use it in war surgery. Its great advantage is that it avoids the necessity for an anæsthetic; against this, however, is to be put the length of time over which the treatment has to be spread. In addition, in the majority of cases we meet nowadays among the wounded the stiffness is of a severity that will not readily yield to this form of treatment.

Forcible correction of the position of a joint under an anæsthetic is, as regards its technique, but not as regards its aim, identical with the operation described above as forcible mobilisation of a joint. The operator

should always commence by exaggerating the deformity; in other words, he should proceed first to break down the adhesions on the side of the joint where the ligaments and soft parts are the less retracted. The advantage of this is that it gives greater freedom of movement and greater momentum for the attack on the more dense adhesions and the more strongly retracted ligaments on the opposite side of the joint—the tissues that are really responsible for the maintenance of the mal-position. The surgeon should be satisfied and desist only when a position has been reached that constitutes a slight exaggeration of the required correction.

In the case of stiff fingers—stiff in flexion or in extension—and of stiff hyper-extended toes a much more simple procedure suffices; the correction can be effected by a single sudden twist of the surgeon's fingers. When thus forcibly extending a finger or a toe the surgeon will often feel something give way with a crack; at the same time a tight band or cord will become evident in the forearm or leg; one's impression is that adhesions between tendon and tendon-sheath have suddenly snapped, with a consequent sudden transference of the force of the manipulation to the freed tendon and its muscular belly. Very often after such forcible manipulation of fingers it is quite remarkable, once the extreme initial pain has subsided, how free from pain any passive movement of the fingers now becomes, even though carried out within a few minutes of the performance of the operation. Occasionally in the case of the toes forcible correction results in a transverse tear of the retracted skin across the bottom of the groove separating the plantar surfaces of the toe and the sole.

I have only once had to perform forcible correction and mobilisation for simultaneous flexion of both the wrist and the fingers, in a case in which the extreme flexion brought the tips of the fingers into contact with the palm of the hand. But very numerous are the occasions on which forcible correction of the various joints of the foot becomes necessary, joints for the most part stiff in equino-varus, whether the stiffness be simple, complicated by retraction and shortening of the tendo Achillis, or of a primarily paralytic origin. Where the stiffness is the result of or accompanied by muscular retraction or paralysis, the forcible correction will have to be followed by operative treatment suitable to the concomitant lesion or disability. Division of the tendo Achillis in particular is very frequently indicated, indeed practically always; where it is not performed, the force used in the correction of the equinus will very often result in a tearing of the tendon from its point of insertion into the os calcis. The performance of a tenotomy is preferable to this.

The differences in after-treatment and results between this operation of forcible correction and that of forcible mobilisation are great; after the former operation the limb should be immobilised in plaster for about three weeks in the corrected position. For the next fortnight the patient should be made to walk about in the plaster, the sole of which may if necessary be specially reinforced. Although in some cases it will be wise in order to avoid all risk of recurrence of the equinus to prescribe an appliance with elastic traction for night wear or during walking, in the majority of cases no such support will be necessary. In some cases a variable amount of

restoration of mobility will eventually take place; in the majority, however, such is not to be looked for, the ankle joint remaining permanently stiff in the right-angled position. If the slightest amount of varus remain uncorrected, the influence of the body weight will inevitably and progressively increase this, and no appliance or surgical boot that can be ordered will succeed in preventing it. In cases where the sole has been brought into its normal relation with the ground nothing can increase the range of mobility of the foot better than walking (see page 276); on the other hand, if the foot be deviated the least little bit into varus nothing will make it worse so surely or so rapidly.

Where there persists not indeed any actual varus but however slight a tendency to its recurrence, the outer part of the sole of the boot should be raised (see p. 269).

Sometimes full correction of the equinus cannot be effected at the one sitting, the foot cannot be got quite to an acute angle with the leg; such persistence of the slightest degree of equinus will almost certainly result in a relapse of the varus.

Moreover, since such forcible correction results in the foot remaining tender for some time, when the patient first commences to walk he very often exhibits a tendency to walk on the outer border of the foot; such a tendency should be checked at once.

The case should then be treated as a case of but a slight degree of stiffness.

In cases where the deformity has been marked a night shoe should be ordered (in some cases indeed it may be wise to insist on the patient wearing an appliance during walking for some weeks at least);

this shoe, which should be fitted with elastic traction, should consist essentially of a sole piece and a leg piece connected together by a hinge behind the heel and by two elastic bands or coiled springs that pass one on each side of the ankle joint.

In any case the patient should certainly have the outer border of the sole of his boot raised so that he walks in slight valgus; indeed such a boot should always have been prepared in advance so as to be ready for use as soon as the patient comes out of the plaster.

Gymnastic exercises to increase and maintain the range of flexion of the ankle joint as well as careful re-education in walking should always be carried out; this latter is an infinitely more valuable method of treatment than any amount of passive mechanical exercises.

The position of the foot being thus corrected, massage should be now commenced to lessen the œdema and to increase the strength and development of the wasted muscles; such treatment which before, on account of the deformity and inability to walk, was useless can now prove of the very greatest advantage. Hence the following up of an operation of no very great severity with such valuable forms of accessory treatment should in the course of eight to ten weeks result in the conversion of a deformed and useless foot into one whose range of movement it is true remains more or less limited, but in which the range of flexion is sufficient and well adapted to walking, in which the sole can be brought into normal relation with the ground, and through which the transmission of the body weight causes no pain.

The forcible correction of such a foot, however, is in many cases neither a simple nor a short operation; it often takes an experienced surgeon from fifteen to twenty minutes; hence for its performance ethyl chloride is not a suitable anæsthetic; either ether or chloroform is necessary.

The classical precept, laid down somewhere about 1860 by Adams, and re-discovered time and again since then, insists that first of all the varus element of the deformity should be corrected before the equinus element; in this way the elevated posterior tarsus is used as a fixed point against which the force necessary in the manipulation of the mid-tarsal joint may be exerted. After the full correction of the varus the equinus should be next attacked, care being always taken that the correction is effected at the ankle joint—which means real correction, with a lowering of the heel—and not at the mid-tarsal joint, hyper-extension of which results in an apparent correction that does not alter in the least the elevation of the heel. Finally, any hyper-extension of the toes should be dealt with. Sometimes, too, a co-existent stiffness or deformity of the knee joint may require attention.

1. *Correction of the varus.*—The foot should project somewhat beyond the edge of the table whilst an assistant holds the leg firmly and steadily with the knee fully extended. The surgeon should then face the foot, and with one hand—the right in the case of the left foot, and *vice versa*—fix the posterior tarsal bones and ankle joint; with the other he should grasp the anterior part of the foot, the fingers on the dorsum, the thumb across the sole, and commence as usual by increasing the deformity—the extent of

the varus; the fore-part of the foot should be then suddenly and forcibly wrenched into valgus, the force being chiefly exerted through the thenar eminence of the surgeon's hand to the anterior part of the first metatarsal bone. This sudden jerk should then be followed by firm, steady pressure in the same direction, a pressure into which the operator standing with his elbow flexed to a right angle and buttressed against his side should put the whole weight of his body; in the meantine his other hand should draw the posterior tarsus in the opposite direction. It should never be forgotten that in accordance with the shape of the articular surfaces of the mid-tarsal joint the fore-part of the foot should in the correction of varus be forced upwards and outwards as well as externally rotated, should in the correction of valgus be pulled downwards and inwards and internally rotated.

2. *The correction of the equinus.*—It now becomes necessary to deal with the ankle joint, and that in the following manner:

Grasping the posterior part of the foot between his two hands, the fingers crossed on the dorsum and the thumbs meeting on the sole, the surgeon should gently draw the foot as far into equinus as possible and then suddenly and violently wrench it in the opposite direction as far as possible into calcaneus; during this stage of the manipulation strong adhesions will usually be felt to give way. The operator should take special care to apply the force through his thenar eminences to the under surface both of the mid-tarsal joint and particularly of the os calcis itself, for it is most necessary to ensure full correction of the position of this bone, to raise its anterior end and so to depress the heel. When a certain range of movement has

thus been obtained in the ankle joint, complete correction of the equinus should be effected in the following way: whilst keeping the knee extended the assistant should raise the whole limb to an angle of 45 degrees with the table; the surgeon should then place the middle part of the sole of the patient's foot against the front of his chest just below the clavicle, and supporting with both hands the lower ends of the bones of the leg, should use the whole strength of his shoulders to force the foot by a series of sudden jerks into the position of full calcaneus—a position in which it forms an acute angle with the leg.

One should be able to judge either in advance or else during the first stage of the correction whether the retraction of the tendo Achillis is such as to render necessary its elongation; if so, this should be done after correction of the varus, but before manipulation of the ankle joint.

3. The surgeon should never forget to manipulate the toes into good position, for the clawing of these, and especially of the great toe, constitutes a very considerable disability.

4. *Correction of deformity at the knee joint.*—Where in addition the knee joint is stiff in flexion it is essential that this deformity should at the same time be corrected, for its persistence would render useless all the energy expended in the manipulation of the foot.

In two cases, each with the knee stiff in flexion as well as the foot in equinus, I managed at two sittings, and without having to resort to tenotomy of the hamstrings, to obtain satisfactory correction of both deformities; at the first operation the foot was fully corrected and the knee but partially, and the whole

limb immobilised in plaster right up to the pelvis; at the second, a month later, further correction of the position of the knee joint was effected, so that the end result in each case was a foot fixed in flexion and a knee joint fixed in almost complete extension. Both patients, formerly absolute cripples, are now able to walk perfectly well without even the assistance of a stick.

5. *The dressing and method of fixation.*—The short incision through which the tendo Achillis has been lengthened should first be dressed with aseptic gauze and then the limb covered with a layer of stockingette and the foot fixed in plaster in the position of calcaneo-valgus. It is essential that the patient should be kept well under the anæsthetic, and also that the foot should be held firmly in position until the plaster has dried.

I usually make a plaster gutter splint that leaves the dorsum of the foot and the front of the ankle free to accommodate the swelling that invariably takes place, and concerning which I shall have more to say in the next section.

6. *The after-treatment.*—After such manipulation there always occurs a considerable amount of inflammatory swelling and of bruising of the foot; for two or three days the pain is very severe and demands relief by morphia. Save, however, in the one rather exceptional case that I have referred to above, I have never seen infective inflammation and suppuration, as I have always taken good care that all my other cases have been well and soundly healed, and that for a very long time before I have consented to operate.

After the subsidence of the acute pain and swelling

the foot should remain in the plaster for a month; during this time, however, daily manipulation of the toes should be considered a matter of the greatest importance, otherwise they will rapidly revert to their clawed condition.

At the end of the third week the patient should be made to walk about in the plaster, which may be specially thickened for that purpose with further layers of plaster bandage.

At the end of the fourth week the plaster should be removed and the patient encouraged to commence walking.

From this moment, however, special attention should be paid to the patient's re-education in walking. In such cases walking may have either the very best or the very worst influence; the best, where it is carried out properly, the sole flat on the ground; the worst, where it is accompanied by the least deviation of the foot into varus or equinus.

PART II

NON-ARTICULAR LESIONS

CHAPTER III

SCARS: LESIONS AND DISABILITIES OF MUSCLES

1. Scars

A SCAR may interfere with normal joint action in one of two possible ways: by directly involving a muscle and so affecting the efficiency of its contraction, or by forming a hard retractile fibrous band of variable depth that beyond a certain point completely arrests further movement of the joint in a given direction.

The involvement—in many cases of no great extent or depth—of a muscle in a scar is in most cases accompanied by a certain amount of atrophy and sclerosis of the rest of the muscular belly; but often this is very slight, so that the disability is largely the result of the adherent scar. Such a condition is easily recognised by the depression of the scar that takes place when the muscle contracts. In cases where the perfect functioning of the muscle is physiologically important, as it is especially in the muscles of the forearm, excision of the scar followed by suture of the wound is certainly indicated, and usually gives very satisfactory results.

The second of the two conditions that interfere

with joint action is the existence near the joint of a large dense mass of scar tissue replacing the soft parts that have been destroyed over a variable extent and depth. In civil life such a condition is not infrequently the result of a severe burn that has destroyed the skin and subcutaneous tissues of the neck, of the anterior wall of the axilla, or of the flexor folds of the elbow, of the hip, of the knee, or of the fingers. In the one direction the movement of the affected joints remains quite free; beyond a certain point all movement in the opposite direction is, however, prevented by the band of scar tissue, the gradual retraction of which, moreover, tends always to draw the limb into a position more or less abnormal or disabling. Here again excision of the scar tissue, followed by skin grafting or some other plastic operation, is indicated, and gives excellent results.

The burns met with in war surgery—which are not at all rare—should be treated along the same lines. I have not seen in soldiers, however, any of such enormous scars as result in civil life from vitriol burns, or in children from their clothes catching fire or from their grasping a red-hot iron bar.

In war surgery the principle of the operation is the same, although, especially in the regions of the body just indicated, its performance is much more difficult when the scars resulting from the prolonged suppuration of extensive war wounds are large and deep. All around the mass of scar tissue—which, indeed, in part represents them—the muscles are sclerosed and retracted; whilst very often vessels and nerves are surrounded and involved. Because of recrudescence of activity on the part of germs that have remained dormant over long periods in

the islands of scar tissue, healing by primary union not infrequently fails.

As in the case of the scars that result from burns, one should never be in a hurry to operate; for, as every one knows, scar tissue in time—usually a matter of months—gradually becomes softer and more yielding, so that, provided that there is no compression of nerve and vessels, one should always wait to see how far such improvement will go.

Where—and this occurs especially often in the case of the knee joint with a scar in the popliteal space—the contraction of the cicatricial mass pulls the joint into some permanent mal-position (flexion of the knee joint, permanent adduction of the arm), forcible correction of the deformity should be carried out only in slight cases, always in several stages, and then only with the greatest caution; one should always beware of tearing of the scar with rupture of the vessels enclosed with it.

Some have considered that the normal process of softening and progressive increase in suppleness of scar tissue can be hastened by means of such various physical agents as massage, ionisation, exposure to the X-rays and to radium. As regards this point it is difficult to form an accurate judgment, for before the war we hardly ever saw such extensive masses of scar tissue. But from my own personal experience—considerable of burns, though not of military cases—I am inclined to believe that the effect of such physical remedies is but slight. As the patients remain for many months attending a physiotherapeutic centre, it seems to me that the improvement attributed to these various agents is really due to time. Many of these cases would do better working

at their homes than undergoing an occasional treatment with radium, and meantime wasting their time in idleness. I have, moreover, seen several cases of obstinate ulceration from radium burns; radium is inferior to the lance of Achilles, in that it cannot cure its own unfortunate effects.

2. Muscular Lesions and Disabilities

A. Nomenclature. General Consequences

(*a*) *Nomenclature.*—Conditions that interfere with muscular contraction are of two chief varieties:

(1) Lesions, the result of actual immediate involvement of the muscle in the initial trauma (*e.g.* the division or destruction of muscular bellies and of tendons), or its later involvement in the inflammatory or reparative process (*e.g.* sclerosis, retraction and adhesion of muscles).

(2) Muscular lesions that result secondarily from lesions of the vascular and nervous systems. I will give an example only of the vascular troubles; many patients in whom the main arterial trunk of a limb has been tied, especially in the case of the lower limb, develop a disability in the muscles of this limb; these become very easily fatigued, and the patient is of very little use for marching. Among muscular lesions secondary to injuries of the nervous system are to be included a certain form of atrophy plus contracture that is probably reflex in origin, contractures purely hysterical, and paralyses from division, anatomical or physiological, of nerve trunks.

(*b*) *General consequences.*—(1) The destruction or paralysis of a muscle or the division of its tendon

results, in the first place, in abolition or loss of the active joint movement normally effected by its contraction.

(2) The second consequence, of very great importance to the surgeon, is the production of deformities the mechanism of which is very easily understood.

When a sclerosed muscle retracts or shortens it draws towards it the movable bony lever into which it is inserted; a typical example is the production of an equinus position of the foot by retraction of the gastrocnemius and soleus (often called "shortening of the tendo Achillis"). A similar result occurs from the contracture of any muscle or group of muscles which comes to exert a permanent pull on the bony lever in the direction in which they normally act on it.

When all the muscles that normally move a joint are paralysed this joint hangs perfectly flail and inert; there is no power of active movement in any direction. Where, however, only a certain number are paralysed, their unparalysed antagonists draw the bony lever in their direction, away from that of the paralysed muscles.

(3) Each of these individual lesions often co-exists with such ankylosis or stiffness of joints as we have studied in the earlier part of this book.

B. Direct Lesions of Muscles

Division of Muscle and Tendon; Loss of Muscular Substance

1. There is nothing of special importance to add to the detailed classical description of the phenomena and treatment of cut tendons found in ordinary

text-books. Occurring in the fingers or at the wrist —the latter the commonest site—the diagnosis of this lesion usually presents no difficulties. Provided that suppuration is absent, and that there is no actual loss of substance, the indications for treatment are perfectly simple and clear, viz. the suture of the tendons, primary or secondary according to the circumstances of the case. In war surgery, however, these conditions of successful suture are not often realised. The frequent co-existence of lesions of the bones and joints, the almost constant presence of sepsis, and the occurrence of considerable loss of tissue all serve to render suture at the best inadvisable, at the worst quite impossible.

The extensor tendons are not infrequently divided in their entirety as they lie on the back of the carpus ; this results in loss of all active extension of the fingers and wrist ; and, as their distal ends soon become adherent and firmly fixed by scar tissue to the bone, there is a considerable interference with active and passive flexion of the wrist and fingers ; hence a very serious disability ensues. In the majority of such cases the surgeon is perfectly justified in attempting direct suture where the cut ends can be brought together on hyper-extension of the wrist, or where this is impossible some form of tenoplasty or suture " at a distance " ; the technique of these operations I need not describe. If they fail, nothing has been lost ; if they succeed, much has been gained.

In the case of the tendons of the fingers secondary suture is but rarely feasible ; I would refer the reader to what I have said as to the indications for amputation of the fingers in such lesions.

While dealing with the subject of cut tendons, I

think it is worth while drawing attention to a disability that not infrequently results from cutting through the ligamentum patellæ in arthrotomy of the knee joint carried out through a U-shaped incision. Although healing by first intention ensues, occasionally the quadriceps extensor muscle is thrown more or less completely out of action. I do not wish to imply that on this account this operation should never be performed; sometimes it is quite an indispensable method for an adequate exploration of the knee joint. But I think that on this account alone it should not be allowed to develop into the method of choice or routine.[1]

2. Cases of transverse division of a muscle—which whenever healing has taken place with considerable separation of the ends should be treated by secondary suture—are often disabling quite as much by the atrophy and sclerosis of the fibres that remain intact as by the actual division of the others, and this even where there exists a solid block of scar tissue in the muscle. The extent of this disability should be remembered, and so the transverse division of muscle during operations avoided altogether, except in those very rare cases of absolute necessity or in late reparative surgery where the joint acted on is already ankylosed.

3. A laceration or gap in an aponeurosis through which protrudes a muscle hernia, even although quite narrow, constitutes a not uncommon cause of disability; particularly when it occurs in the leg or thigh, by failing to give proper support to the muscles it

[1] Where the U-shaped incision is performed it is better to separate the tubercle of the tibia. In selected cases the longitudinal incision through the patella is called for.—Ed.

results in an inability to march, although it is quite possible that were peace declared at once a good part of this disability would very quickly disappear.[1]

I will remark in passing what seems to me very often overlooked, that muscle hernias protrude through the gap in the fascia not during contraction but during the stage of relaxation of the muscle.

A good number of these fascial rents and tears, for example, those of the calf, can be quite easily sutured. The fascia lata of the outer side of the thigh, and especially the deep aponeurotic fascia of the antero-external aspect of the leg, are usually, however, far too tense to allow of this, no matter how narrow the gap is; in some of these closure has been quite successfully effected by means of fascial graft.

4. Loss of muscular substance with adherent scars occurs most commonly on both aspects of the forearm, over the antero-external aspect of the leg, and also over the posterior surface of the trunk. The loss of tissue represents that destroyed by the actual trauma as well as that subsequently lost from sloughing due to the virulence of the infection. In this connection I wish to issue a warning against the very free excision of wounds so often carried out to-day in the attempt to get rid of all infected and damaged tissue and so ensure primary union. I quite recognise that frequently most remarkable results are in this way obtained; but in some cases consideration of future function should have their place, and persuade the surgeon to be less radical, to be content with a less brilliant immediate result, with a slower method of healing.

[1] No disability occurs in cases where for plastic reasons fascia is removed.—Ed.

In the forearm and in the leg the usefulness of the muscular tissue above the level of the cicatricial mass is completely abolished, with the result—a greater or less degree of weakness or inertia of the joint below that is controlled by these muscles. In all cases the question arises, Is operation worth trying ?

In the majority of cases it is not ; after excision of the scar and freeing of the muscle ends the distance separating these will be found to be too great to allow of suture of the lower tendinous part to the upper fleshy muscular belly. I have seen cases of this sort, however, in which it was proposed to explore and free the main nerves of the limb—a perfectly useless and ridiculous procedure. One of such cases was that of a patient with non-union of the shaft of the radius a little above its middle and with extensive destruction of the flexor and some involvement of the extensor muscles of the forearm ; liberation of the muscles having failed to improve the use of the hand, the surgeon actually proposed, after the lapse of a few months, to explore the nerves above the level of the lesion.

Now this constituted an error of diagnosis that is far from uncommon, although quite easy to avoid—that of mistaking loss of motor power from destruction of muscle for that of an actual paralysis. Such a mistake can be easily avoided by a careful examination of the sensibility and of the movements that can still be carried out below the scar, by looking for the presence of trophic and vascular disturbances, and especially by determining the exact level of the wound and its relation to the points of origin of the motor branches of the nerves to the muscles affected.

In the case of the patient to whom I have just alluded there existed below the scar no sign of any nerve involvement, and the scar itself was obviously well below the point of origin of the motor branches of the median and musculo-spiral nerves to these muscles. I have dealt with this point at length, because on many of the patients' labels I have noticed this obvious error of diagnosis. In these apparently the existence of a nerve lesion was all the more believed in because of the electrical reactions of the lower ends of the divided muscles; but of course the reaction of degeneration is to be expected in these lower ends, which, normally almost entirely tendinous, are now sclerosed and degenerated.

Whilst in these cases operations are of but little use, equally inefficacious as regards the actual muscle lesion are both mecanotherapy and physiotherapy. These are of use, however, in strengthening and training the muscles that have escaped destruction and in teaching the patient to make use of movements that in the case of the hand, however mediocre, are almost always better than those of an artificial hand. In this way can be appreciably shortened the time necessary for the functional adaptation and manual re-education of the patient. In the case of the foot, where in addition to loss of motor power is developed mal-position at one or more joints, the surgeon may be justified in performing late amputation.

In the trunk a certain number of cases of excision of the scar followed by muscle suture have given good results;—for example, in the dorso-cervical region to prevent the head falling forward; in the lumbo-sacral region to assist in the balancing of the body on the

pelvis. The wearing of a spinal support or jacket is never of much use.

C. Sclerosis and Secondary Retraction of Muscles

1. Etiology.—There is no need to dwell at length on the sclerosis, often indeed combined with actual loss of substance, that results from the occurrence of suppuration, localised or diffuse, either in or between muscles. Such is met with in a greater or less degree in all regions of the body, and is often accompanied by sclerosis, compression or chronic inflammation of nerves and vessels, so that to the muscle disability are added vasomotor, trophic, and actual paralytic troubles as well.

Sclerosis may result, however, from mere contiguity of a muscle to a focus of but moderately intense inflammation; everyone is familiar, for example, with the torticollis from inflammation by contiguity of the sterno-mastoid muscle during mastoiditis, or an acute lymphadenitis of the deep cervical glands; such a slight superficial myositis may in exceptional cases be followed by a permanent extensive and severe sclerosis of this muscle.

Certain traumatic lesions that do not include an open wound may have a similar result. The very serious form of sclerosis of the flexors of the fingers that we occasionally meet with in cases of fracture of the lower end of the humerus, less commonly of the bones of the forearm, is an example of this.

This form of sclerosis is most commonly associated with a combination of very great swelling and ecchymosis of the forearm with tight splinting; marked

œdema and cyanosis of the hand follow. In this condition, then, an important pathogenic rôle has been accorded to a local ischæmia from compression of the blood-vessels of the arm, from which is supposed to result a sort of aseptic necrosis, that in turn is followed by a sclerosis of the muscle fibres. This condition has been called ischæmic paralysis and ischæmic contracture ; it is quite possible that it is of ischæmic origin, but it is certain that it is neither a paralysis (the result of a nerve lesion) nor a contracture (an exaggeration of the physiological condition of muscular contraction); it is primarily a retraction following sclerosis of muscle, although it possibly may in addition be associated with vascular and trophic disturbances due to simultaneous involvement in the ischæmic area of vessels and nerves.

A retraction of traumatic origin that is analogous to this ischæmic retraction may be localised to a single muscle, *e.g.* retraction of the sterno-mastoid muscle that occurs in obstetrical torticollis, to which a similar etiology and pathology have been attributed.

I know that the chief part in its production has been attributed by some pathologists to congenital syphilis ; and it is possible that such may play a part of secondary importance in the etiology, although probably not constantly ; if the primary factor in its production be not mechanical, the sclerosis resulting from interstitial rupture of muscle fibres with the formation of a hæmatoma—and this explains the muscular swelling, —how can its frequence in breech presentations, and the predominance of the lesion on the right side, be explained ? One may invoke at will a constitutional condition like syphilis (and why not in other cases of post-traumatic sclerosis of muscle ?), without

which the local injury and hæmatoma might possibly not result in the muscle sclerosis and retraction, but one cannot deny the role of the original trauma.

Again, during the war we have seen a condition of atrophy combined with sclerosis and retraction extend throughout the whole belly of a muscle that has been simply penetrated by a bullet, the track of which has healed in a few days without suppuration beneath the small scabs that mark its points of entrance and exit.

The cause of this seems to me to lie in the considerable force of the concussion imparted by the projectile to the muscle, which immediately becomes extensively infiltrated with blood. This seems to be the more likely from the constant occurrence of swelling and ecchymosis over the whole of the calf following its penetration by a bullet—a penetration which at first appears to have inflicted but very slight damage. Moreover, all surgeons who have operated on recent wounds, whether infected or not, have been struck by the distance from the actual track of the projectile that this infiltration of blood, this contusion of muscles and of intermuscular connective tissue, extends.

The occurrence of this extensive sclerosis and retraction of muscle in such apparently simple wounds, whether its cause be analogous to that of obstetrical torticollis or to that of Volkmann's contracture, need not, then, astonish us. In actual fact, the whole muscular mass has been broken up by interstitial rupture and effusion of blood ; it undergoes degeneration, atrophies to one half its former volume, and retracts. The most marked example of this phenomenon is to be seen clinically after penetration of the muscular bellies of the biceps and of the gastrocnemius. On the other hand, such a train of events occurring on a

limited scale in a muscle like the quadriceps extensor, or a deeply-placed muscle, will very easily be overlooked. Probably for the same reason such conditions have not been noticed in connection with the muscle injuries of civil life, because, like the initial effusion of blood, the process of sclerosis and retraction affects but a limited extent of the muscle; hence a degree of atrophy that is but slight and localised, and of retraction that the antagonistic muscles have no difficulty in successfully resisting.

2. Mechanical Consequences.—Sclerosis and retraction of muscles give rise to two different orders of mechanical consequences :—

1. A loss or weakening of the muscular action that is proportional to the extent of the damage inflicted on the muscle fibres. This needs no explanation or elaboration.

2. A shortening of the affected muscles that results in a permanent approximation of their points of origin and insertion; in other words, in a permanent deviation of the corresponding mobile lever of the joint into which they are inserted in the direction of the normal pull of their contraction. Such deviation is the result of retraction and not of contracture.

Since this deviation is the result of a permanent shortening of the affected muscle, there is thus produced a permanent characteristic attitude of the joint, provided always, of course, that its range of movement is not otherwise restricted by stiffness or ankylosis; and such attitude will become exaggerated whenever the shortened muscle is subjected to tension, *e.g.* by attempting forcibly to separate its points of origin and insertion by some passive manipulation of the joint next above.

For example, retraction of the flexors of the fingers results in flexion of these digits whenever the wrist is brought into a straight line with the forearm; such flexion becomes exaggerated, however, as soon as the wrist is extended; on the other hand, flexion of the wrist, which means an approximation of the points of origin and insertion of the flexor muscles, allows of passive, if not of active, extension of the fingers.

Similarly, when the calf muscles are shortened, flexion of the knee relaxes the tension on them, so that partial, if not full, correction of the equinus position of the foot becomes temporarily possible.

When, on the other hand, an attempt be made to correct the fixed position of the foot with the knee held in extension, the shortened fibrous muscles will at once become taut and stretched, and will be felt to offer a definite, albeit elastic, resistance to the correcting force. I am, of course, here speaking only of cases uncomplicated by joint stiffness.

3. Preventive Treatment.—The slighter cases very often pass unnoticed. In them, as in secondary superficial myositis of the sterno-mastoid, the resumption of normal movements is sufficient to cure the condition, as the strength of contraction of the antagonists prevents retraction and shortening. In military cases such spontaneous cure quite frequently occurs, but there exists on the whole a greater tendency to retraction, which it becomes necessary to counteract by passive movement or by elastic traction, methods of treatment similar to those that I have described as indicated in cases of slight or commencing stiffness and deformity of joints.

In just the same way, the application of continuous extension in a case of inflammatory torticollis is very

often effective in preventing permanent shortening of the muscle.

This preventive treatment when carried out by the surgeon with care and assisted by the collaboration of the patient in the adoption of some form of suitable " home mechanotherapy " will almost always succeed in preventing definite or severe retraction, and so in avoiding the necessity for operation.

4. Surgical Treatment.—The various forms of physiotherapy are powerless to remedy the loss of function of the fibres that have become sclerosed; carefully regulated exercises can improve the condition solely by increasing the strength of contraction of the muscular bundles that remain intact.

As regards the mal-position of the limb, as soon as the sclerotic process has come to an end this similarly becomes fixed, and all mechanical methods of correction will fail; too often such are persisted in when operation alone can effect the correction.

Retraction of the flexors of the forearm has been treated by two different operative procedures:

1. The liberation of the muscles combined with tenoplasties, with the object of elongating the shortened muscles and of allowing them to work more smoothly.

2. Shortening of the two bones of the forearm by the removal by a cylinder from the shaft of each. This serves to give more play to the shortened muscles.[1]

Neither of these operations, however, has yielded very satisfactory results; in many cases no improvement whatever has followed. As, moreover, both

[1] M. Leriche showed at the Société de Chirurgie a case in which in order to increase relatively the length of the muscles he resected the lower half of the astragalus. I have never met with a case too bad to be cured by elongation of the tendo Achillis.

procedures are both tedious and difficult, they have not been widely practised.[1]

On the other hand, in the retraction of single muscles excellent results are given by tenotomy; at least in the case of the gastrocnemius, for the results of tenotomy of the biceps cubiti are not quite so good. Fortunately it is but rarely indicated in the case of this muscle, possibly because of the extending influence of the weight of the arm, at any rate in those cases in which the use of an arm sling has been prohibited.

Retraction of the gastrocnemius and of the soleus, although these muscles are in reality both extensors and adductors (see page 266), results in the production of a simple equinus position uncomplicated by any varus deformity; the mechanical consequences of this have been studied on page 274 Such a condition should never be treated by a surgical appliance or boot (see page 276), but always by tenotomy of the tendo Achillis.

The simplest method of performing this operation —as it is the original method—consists in mere transverse division of the tendon; this is very easily carried out in accordance with the technique sufficiently well described in elementary text-books of operative surgery; it is unnecessary to repeat it here.

After division of the tendon the foot should be forced well into flexion (to ensure a good result the

[1] In the treatment of this condition I would refer the reader to another procedure which gives much better results than operation. The wrist should be fully flexed. so that the fingers become comparatively relaxed. Separate splints should be applied to the fingers, and by degrees the metacarpo-phalangeal joints should be extended and a splint placed from the wrist joint to the tips of the fingers. After the hand is straightened the splint is used to gradually extend the hand upon the wrist until dorsiflexion is complete. The structures are in this way made to yield in the direct order of their tension. The wrist should be dorsiflexed for a considerable time.—Ed.

foot should form an acute angle with the leg) so that the heel descends carrying with it the lower end of the cut tendon, which thus becomes separated from the upper; a separation of from 7 to 8 centimetres can in this way be effected. The foot should then be fixed in plaster in this position so that a cicatricial band comes to form within the tendon sheath, which so reunites the two ends of the cut tendon.

By performing the operation on these simple, though classical, lines the following advantages are supposed to accrue:

(*a*) The whole operation can be performed subcutaneously.

(*b*) Local anæsthesia alone is necessary.

I must confess that the first of these advantages does not in the least appeal to me; I do not consider that in this region where the presence of a scar is of no importance whatever there is anything to be gained by making the operation a strictly subcutaneous procedure. As there is no danger whatever from infection, I have always, in hundreds of cases of congenital talipes, exposed the tendon by a median longitudinal incision, and in this way have always made certain that I have completely divided the tendon.

Elongation of the tendon, of which I am going in a few moments to give an account, can also be easily performed under local anæsthesia, and in many cases I have so performed it. In most cases, however, except in the presence of some special medical indication or by special request of the patient, I prefer a general anæsthetic; and this for reasons that I will give further on in this chapter, but reasons that apply equally to the case of simple tenotomy. I do not for one moment believe that the persistence under local anæsthesia of

any degree of contracture that may be superadded to the retraction is of any value in indicating to the surgeon when he has divided a sufficient amount of the tendon to correct the shortening due both to the contracture and to the retraction. Operate always by the open method ; always cut the tendon completely through, and where its sheath is adherent to it cut that too, and you will invariably find that you have divided just enough, neither too little nor too much.

But as against these two quite hypothetical advantages of simple tenotomy there is to be set a definite disadvantage—the possibility of failure of union between the ends of the cut tendon ; this results in the development of a very disabling calcaneous deformity. It is impossible to specify with any certainty in what percentage of cases this occurs ; since I have never seen it follow simple tenotomy for congenital talipes in children, I am inclined to believe that it is quite exceptional, and that it occurs only in cases in which very wide separation of the ends of the cut tendon has taken place. I believe, moreover, that the likelihood of its occurrence can be minimised by operating well away from the insertion of the tendon, well above the heel. The fact remains, however, that at the Grand Palais we meet from time to time with cases in which it has occurred, and in which it certainly cannot be attributed to the occurrence of sepsis.

Now, in elongation of the tendo Achillis we have an operation almost as easy to perform, and one, moreover, which can never result in failure of union.

A very simple method of its elongation consists in dividing the tendon obliquely so that the lower end, descending along with the heel, retains at the same

time through its tapering point contact with the upper end; the elongation in such a case being not equal to the distance between the points of entrance and exit of the knife on the opposite borders of the tendon.

This method, however—especially if a considerable amount of elongation is required—entails some risk that the reconstituted tendon will lack sufficient thickness and strength. But by a slight modification it is very easy to ensure a thickness one-half of that of the original tendon; this is quite sufficient for all practical purposes.

If the whole thickness of the tendon, instead of being cut obliquely, be split down the middle line over a length of six to seven centimetres, and if at each end of this incision the opposite halves of the thickness of the tendon be cut transversely, the whole incision being thus Z-shaped, there will be fashioned out of this length of the tendon two rectangular flaps, the lower of which will, when the foot is flexed, slide on the upper. The thickness at the seat of union of these two flaps will remain that of the original tendon; above and below this for some distance the tendon will be but half of this thickness.

As after oblique division, the edges that remain in contact may be sutured together; if there be but one centimetre of overlapping, this is not worth while.

As a matter of fact, as Delbet first showed me, one can in most cases, by omitting the vertical incision, arrange a more natural means of maintaining the surfaces in contact; after making the two semi-divisions of the thickness of the tendon, and on forcibly flexing the foot, the length of tendon between the two incisions will be seen to split into two halves

that glide on each other, one upwards, the other downwards with the heel.

The only restriction which I would propose to the use of this excellent method—which indeed I have myself adopted—is in connection with cases in which there co-exists however slight stiffness of the ankle-joint.

In such cases the tendon will often be found to be red in colour, rough, and surrounded by thickened and vascularised connective tissue. Under these circumstances the cleavage of the tendon will probably require the application of a force greater than can usually be brought to bear. In the first case of this kind that I met, trusting in the usual way to the force of the correction to split the tendon, I succeeded instead in tearing it away from its insertion. The final result was good, the tendon re-attaching itself; but it is quite conceivable that it might have failed to do so, so that in other cases of this type I have always taken the precaution to split the tendon myself before flexing the foot; this has, of course, no real disadvantage except that the result does not look so neat.

Cases of this type are, moreover, far from rare; and as correction of the deformity takes great force, and as, moreover, the condition of the tendon cannot be foreseen, I prefer, except in special circumstances, to have the patient under a general anæsthetic.

After correction of the deformity, the foot, being brought to a right angle with the leg—except, indeed, where this is impossible on account of some bony deformity,—should be fixed in plaster for three weeks; during the last week, however, the patient may be allowed to walk about in the plaster.

At the end of the three weeks, when the plaster has been cut off and the stitches removed, in the great majority of cases the patient will be able to walk about at once in an ordinary comfortable boot.

A night shoe should, however, be worn for a further two or three weeks, preferably one with elastic traction so arranged as to keep the foot well flexed; several times a day the patient should perform exercises to increase and maintain the range of this flexion; and a certain amount of re-education in walking will be advisable, care being taken that during walking the sole, and especially the heel, is brought into normal contact and relation with the ground (see p. 270 and p. 314).

D. Contractures

Nerve lesions may result in abnormalities of joint position in two different ways: (1) by causing paralysis, (2) by causing contracture of muscles. The occurrence of either of these conditions, paralysis or contracture of muscles, will interfere with the normal equilibrium of the muscles controlling the joint; thus in paralysis the unparalysed antagonists find their action unopposed, whilst the mere existence of contracture of course implies an exaggeration of the normal action of the affected muscles.

In both cases the predominant muscles draw the bony lever of the adjacent joint into which they are inserted in the direction of the pull of their normal contraction. Such deviations from the normal position occur especially in the hand and in the foot; those of the foot have a very special interest to the orthopædic surgeon.

A permanent deviation or mal-position—which, however, in the case of paralysis is not of constant occurrence—having become established, the general indications for treatment are identical with those that obtain in all cases of club-foot, and may be summed up in the two phrases: "correct the deformity," "maintain the corrected position." The treatment of these cases of club-foot by contracture differs, however, at any rate in one important particular, from that of most other varieties of club-foot, in that in typical cases the chief difficulty consists not in the correction of the deformity but in the maintenance of the corrected position. In other words, despite the correction of the abnormal position the disturbance of muscular equilibrium still exists; hence arise in these cases certain indications for treatment by external appliance or by surgical operation, and between these two alternative methods of fulfilment of these indications the surgeon has to choose.

Both in cases of paralysis and of contracture it often becomes necessary, after correction of the deformity, to fix the joint by means of a special operation, that of arthrodesis, which is in reality the production by surgical means of an artificial ankylosis in good position.

A. Simple Contracture and Organic Contracture

True contracture is nothing but a condition of permanent contraction without the occurrence of any organic pathological change in the muscle fibres. Such is seen in its typical form, though associated with exaggerated reflexes, in an organic lesion of the central nervous system with degeneration of the

pyramidal tracts, and also in purely psychic or functional disorders in which no organic change can be detected either in the muscle itself or in the nervous system.

What is the nature of this psychic condition? It is difficult to define, for it is impossible to draw a clear and definite distinction between true hysteria, to-day known as pithiatism, which seems to be a genuine disease, and actual simulation. But the fact, now recognised, that Babinski has been insisting on for several years, is that hysteria is not the great "simulator of disease" that formerly it was considered. It is quite incapable of setting up organic changes in the tissues. Contractures, paralyses, stigmata are all purely psychic in origin, the result of suggestion; all are capable on the institution of counter-suggestion of disappearing without leaving any traces.

Hysterical contractures, with which alone in this chapter we are concerned, are distinguished by being unaccompanied by either muscular atrophy or by modification of the deep reflexes; they disappear under anæsthesia and during sleep; whilst, on the other hand, they are often accompanied by other hysterical manifestations.

Such purely pithiatic contractures, resulting in the adoption of positions that are often most bizarre, are very frequent among the wounded, whether as the result of a definite localised wound of a general concussion or of some trauma of indefinite nature.

These cases are to be contrasted with other cases, in which in their most characteristic form the contracture is accompanied both by muscular atrophy and by exaggeration of the deep reflexes.

At first sight the general resemblance between these two classes of cases is very great, and our predecessors would have had no hesitation in labelling those of this second class hysteria as well as those of the first.

For cases of this class are often hysterical; and even if not malingerers, are often men who are not afraid to exaggerate their disability, to make use of, indeed to abuse it. This class of case was but rarely met with before the war, and then only in industrial accidents. To-day they are of frequent occurrence —these cases of contracture that undoubtedly in the first place was associated with an organic lesion, a sprain or a slight wound, but that persists for months or years after this is cured or healed, that is only too likely to persist until the end of the war.

Why this difference between civil and military cases? Probably because these slight primary lesions passed unnoticed so long as the patient had no interest in their exploitation, and because present circumstances have created such an interest.

The occurrence of muscular atrophy in connection with joint lesions has long been known and well recognised. A sprain of the knee joint at once results in a perceptible softening in the quadriceps muscle, and its wasting becomes obvious in the course of a few days. Whilst so perfectly obvious and easily perceptible in the case of large and superficial muscles and joints, such wasting is probably of constant occurrence in all joint lesions, varying, however, in degree according to the nature and severity of the lesion, and also, by the working of factors so far unknown to us, according to the particular joint affected. This muscular atrophy is a

most important element in the functional disability of such inflammation or injuries of joints; and if I do not deal with it at length in this book, it is because its occurrence is well known and the importance of its treatment so well understood.

It has been definitely proved that the wasting is due to the joint condition and not to any immobilisation of the limb; after much clinical and experimental investigation the theory of its reflex origin has become pretty well established. This, however, has not deterred certain surgeons from taking the opposite view and persisting in regarding it as the result of immobilisation; hence they refuse to immobilise inflamed and injured joints. They sin through ignorance, for we know that the atrophy is reflex; moreover, as is to be expected, their results are for the most part deplorable. It is well to draw attention to these facts whenever opportunity occurs, for if we judge by the great numbers of cases of joint lesions (without wounds) that are being treated by mechanical methods in the physiotherapy centres, it would seem that this false doctrine and pernicious practice are gaining ground. In the first place, such cases should never be sent to such centres; and in the second, they should never be kept there. Immobilisation, it is true, results in a certain amount of atrophy; any wasting from this cause, however, is soon and easily made good as soon as active movement is resumed, whilst wasting of reflex origin is very much more resistant to time and treatment.

This reflex atrophy certainly occurs in its most characteristic form after joint injuries, but it would be a mistake to regard it as occurring only in association with such lesions. It is most probable that in

a somewhat less marked degree it occurs in fractures, and even possibly after any form of injury whatever. I well remember reading twenty years ago some very interesting observations recorded by Klippel and his pupil, Daniel of Achardon, of the occurrence of atrophy after injuries, and especially after certain burns in childhood, in which a true arrest of development became more and more evident on comparison with the sound side. There is no reason, however, why such atrophy should take place only in children.

As a matter of fact, putting on one side cases of direct injury of muscle either from the initial trauma or from the resultant suppuration, we have all been struck by the frequency and the extent of the atrophy that has occurred even in the absence of any bone or joint lesion.

When associated, then, with muscular atrophy—its existence is always a point that can easily be verified —we cannot attribute to hysteria pure and simple any contracture that may be present in any part of the body. We return, then, to the subject of contractures. Such are often associated with an exaggerated state of the deep reflexes that may in some cases give rise to an epileptoid clonus—a similar clonus is quite common in certain amputation stumps ; this variety of contracture, then, is something new, something with which before the war we were quite unfamiliar. It is very probable that it, like the atrophy, is of a reflex origin. The associated atrophy may be slight and hence easily missed, but it is in my opinion constant in these cases which it is most essential should be clearly distinguished from cases of hysteria if they are to be successfully treated. For though there certainly does exist in these cases

a psychopathic element, it is no less true that there is also a definite material organic lesion against which treatment by suggestion is as powerless as the coercive treatment that one would use with a malingerer.

This condition is in a way analogous to that in which an association of early hip-disease exists, with a general hysterical condition, and presents a symptom-complex exceedingly difficult to interpret; among all the local and general signs of hysterical hip it is not at all easy to detect or be sure of the slight signs of the genuine disease, and missing these means the institution of treatment that is all the more deplorable in its results because for a few weeks or months it seems to be effecting a cure.

Similar cases of contracture are to be observed associated with the aseptic encysting of tiny pieces of metal—a few millimetres in diameter—in muscles, tendons, ligaments, and in the articular ends of bones. I remember, for example, a patient with a small piece of shell—some 3 to 4 millimetres square—embedded in one of his femoral condyles near the articular cartilage, originating a spasm and contracture of the thigh muscles that held the knee fixed in extension. I removed it; the contracture ceased under the anæsthetic and never recurred. There was a certain amount of atrophy present, with some exaggeration of the tendon reflexes, an indication of the existence of a condition not purely or wholly psychic; nevertheless, there seemed to me to be some hysterical element in the case, so that I determined to make use of a certain amount of suggestion: for a fortnight I kept the knee flexed, with the heel against the buttock, in a starched bandage; at the end of that period the

knee was left free, but not the slightest tendency to relapse ever appeared.

What exactly do we mean by this expression—neuropathic or psychopathic state? Apart from its application to a certain definite, well-recognised class of case, it is largely no more than a mask for our ignorance. Each one of us has his own powers of toleration of physical pain and disability, of mental anguish and of fear; each of us reacts differently to these disagreeable sensations; and each one of us has a tendency to consider as neuropathic a neighbour whose physical sensibility is above the average or whose powers of endurance are below it.

What is important we should remember is that there exist certain cases of contracture not purely hysterical; that on this account every case of contracture should be investigated with care, especially as regards the existence of atrophy, the state of the reflexes, and the presence of some slight, apparently insignificant focus of irritation. Where such a focus exists, whether in the form of a minute foreign body or of a small painful neuroma of a cutaneous nerve, treatment should commence by its surgical removal. The contracture should afterwards be treated directly, whether by general suggestive or by local physical or surgical means.

That in all cases non-operative treatment should first be given a serious trial no one will contest: massage, active and passive mobilisation, gymnastic exercises, and re-education of the muscles are all indicated; and treatment by suggestion or by coercion should be utilised according to the seeming importance of the superadded psychic element judged to be present in each particular case.

But when these methods fail, as they not uncommonly do, it is quite wrong to persist with them for months and to forget that the deformity has originated in an organic lesion over which the patient has no control; and it is just in these cases that, despite what others have said about it, in my opinion, arise certain indications for surgical intervention that I wish to put before the reader.

Those contractures in which hysteria plays an important but not an exclusive rôle may affect any part of the body, may be of any degree of severity, may reproduce any deformity from scoliosis or kyphosis to a fixed flexion or extension of a single finger. They most commonly, however, affect the hand and the foot.

B. Club-foot from Contracture

I have never thought it wise to intervene surgically in a case of contracture of the hand, the various forms and shapes of which I will not here attempt to describe. I have thought fit, on the contrary, in a considerable number of cases of fixed equino-varus deformity, the result of contracture of the leg muscles, to perform various tenotomies and arthrodeses. For reasons I have already given, the subject of the causation and treatment of these contractures is a very difficult and obscure one, for in any case it is not clear—perhaps it never will be—what proportion of the deformity and disability is due to the general psychopathic state and what to the initial local lesion. But at any rate we are certain of the existence of both these factors, and this is of course the chief reason why the indications for surgical inter-

vention are in so fluid and uncertain a state, and form so fruitful a source of discussion and controversy.

1. **Clinical Characteristics.**—At all centres of physiotherapy there are to be met numerous cases of contracture of the foot following a great variety of different wounds and injuries of the lower limb. Most frequently the original lesion has been a wound of the soft parts of the leg or of the foot; sometimes a mere subcutaneous injury, slight degree of trench foot, a sprain or a simple fracture; in other cases there has been a flesh wound of the thigh; in a few merely a slight and insignificant contusion.

The various fixed positions and attitudes assumed by the foot and the toes in these cases are very numerous; nothing could be more erratic than the distribution of the contracture among the various muscle groups of the foot and leg. Most numerous are the cases with the foot in equino-varus, the result of a combined contracture of the tendo Achillis and the two tibial muscles; with the foot in complete internal rotation, unaccompanied, however, by any true adduction at the mid-tarsal joint, so that during walking the whole outer border of the foot alone comes into contact with the ground; with the great toe either permanently flexed or permanently extended. In addition, contracture with the foot in any of these positions may be associated with contracture of the knee either in flexion or in extension.

Very often there is complete loss of power of voluntary correction of the deformity. The patient will sit with his foot on the ground in front of him and simply exhaust himself in vain efforts to move it on the leg; yet during these efforts quite distinct hardening and contraction of the leg muscles will be

appreciable to the observer. In many cases all this expenditure of energy will result in no more than a slight flicker of the toes, suggesting, if not definitely proving, that the immobility of the foot is due not to any actual paralysis or paresis of the muscles of the leg, but to the irresistible fixed tonic contraction of the antagonists.

Voluntary contraction is, however, occasionally possible. I remember one case of severe equino-varus following prolonged exposure of the foot to cold, in which voluntary correction was effected by a very curious series of contortions of the foot. The patient, seated with his leg stretched out in front of him, first contracted his tibialis anticus so that its tendon could be seen standing out in marked relief; this of course produced complete inversion of the whole foot, the sole becoming vertical and looking inwards, and the formerly existing equinus and varus for the time completely disappearing. Then commenced rotation of the whole foot around its long axis in the opposite direction, so that the sole again became horizontal; in the meantime the tibialis anticus was of course relaxed. These movements were executed slowly but steadily, and continuously without any clonus. After maintaining the corrected position for some seconds the foot dropped again into the original position of equino-varus.

In some cases the foot maintains a perfectly normal attitude whilst the patient is standing, but develops a varus position immediately he commences to walk.

In a few cases he can passively correct the deformity himself with his hand. In most cases, however, it is the surgeon who has to perform the correction; this can often be effected by distracting the patient's

attention, and then suddenly and unexpectedly seizing the foot and wrenching it forcibly into normal position. I believe that when this manœuvre fails it is because the surgeon has attempted the hopeless task of attempting a steady, continuous pull against the contracture instead of subjecting the foot to a sudden jerk. In so doing the surgeon will usually become acutely conscious that he is dealing with an actual contracture, for the tendons of the affected muscles will be felt to be acting with great strength against him, although executing at the same time a series of clonic contractions.

When one does not succeed in obtaining full correction the sensation is that of being stopped by something elastic, something that shows a tendency to alternate yielding and contracting, and not by a permanent fixed obstacle in the shape of a retracted muscle or of an organically stiff joint.

These cases of contracture are characterised, too, by the absence of any lesion of the bones and joints or of the soft parts ; there are, however, a few exceptional cases that I will refer to later in this chapter, in which is present a scar on the sole of the foot.

Another peculiarity of these cases of contracture of the foot is that the skin of the foot shows none of those callosities over points of abnormal pressure that are so characteristic of all cases of genuine club-foot. There can be little doubt that this indicates that the position of the foot is not nearly so fixed as one is at first inclined to believe ; the foot almost certainly relaxes to a more normal position during sleep, although this is not a point easily verified ; quite possibly, too, a certain amount of correction takes place inside the boot during walking, although

this again is not easy to detect. In any case this is certainly a peculiarity of these cases that should be carefully borne in mind.

Because of the characteristic syndrome thus presented by these cases there but rarely arises any difficulty in differentiating them from cases of muscular retraction or of real joint stiffness; it is hardly ever necessary to have recourse to an anæsthetic. Such of course provides a certain method of diagnosis, but it has the disadvantage that its usual failure to cure the condition very often serves the patient with a pretext for refusing any genuine operative treatment that may afterwards be considered advisable.

So far, then, we have had no difficulty in recognising the condition as one of contracture; it is in connection with the nature and origin of this contracture that difficulties at once arise.

In many cases the most exhaustive and meticulously accurate examination fails to detect any sign of organic lesion or change whatever; these are cases, then, of undoubted hysteria, neuro-mimesis or pithiatism, whatever term the reader prefers. Such cases are now but rarely met with in the centres of physiotherapy; they are quite common of course in the neurological centres.

In these cases the contracture is purely psychic in origin; consciously or unconsciously the will persists in impressing on the limb an attitude that no doubt in some cases had at first some temporary local justification, in others none. Are any of these cases malingerers, or are they all genuinely pithiatic? This leads to the threshold of a very obscure problem, for if there exist cases perfectly characteristic of either

class, in which the diagnosis presents no difficulties, there also exists between these two extremes a whole series of cases in which, because of our ignorance of what is normal and what abnormal psychology, because of our inability to draw a definite, precise line between what constitutes the working of the conscious and what that of the subconscious mind, we remain incapable of distinguishing the particularly expert malingerer from the patient who, through fear of again being wounded or further disabled, constantly maintains in some obscure corner of his brain a preference, unconfessed even to himself, for an indefinite sojourn in hospital to a return to duty in the trenches.

In many cases of club-foot by contracture, however, certain signs of organic change are well marked, especially atrophy of muscles and exaggeration of tendon reflexes. As regards the muscular atrophy, one might be inclined in those cases that have after correction of the deformity been fixed in plaster to attribute it to the immobilisation ; but in many cases of marked atrophy there is no history of such fixation ; moreover, the exaggeration of the tendon reflexes would not admit of any such explanation. Babinski has established a definite point of difference between these cases and those of pure hysterical contracture. On giving the patient an anæsthetic the contracture as well as the exaggerated reflexes is found to disappear only in the deepest stages of anæsthesia ; both recur spasmodically as soon as correction of the deformity is attempted, and both constantly return before the patient again becomes conscious.

Are we here dealing with a reflex disorder compar-

able, as is generally held at the present time, to the amyotrophy that accompanies joint lesions? Is it necessary, especially in cases of contracture following frozen feet, to invoke the theory of an ascending neuritis? These questions can be asked, but as yet remain to be answered. All we can say is, that among the wounded there occur numerous cases in which, despite the fact that no nerve trunk has been injured, no muscle involved in suppuration, most remarkable and extensive atrophy of muscle co-exists with contracture and with marked exaggeration of myotatic irritability and of tendon reflexes, so great in some cases that the clonus is like that of an epileptic fit. In addition, in cases following exposure to cold the contracture is often accompanied by a remarkable cyanosis and coldness of the foot, that persists for months even during the heat of the summer.

One other factor in these cases, however, the importance of which cannot be denied, is the frequent association of a general psychopathic condition with the local physical or physiopathic disorder. This does not mean that a club-foot by contracture can be produced at will—for example, after a sprained ankle. It is impossible for any one to produce at will such a combination of atrophy and lack of tone in some muscles with contracture of others, the exaggeration of myotatic irritability and of tendon reflexes, and the general disturbance of the equilibrium among the different groups of muscles.

The deformity seems in some cases to be due to the persistence of a position that should under normal circumstances be but temporary, a position adopted in the first place for the relief or avoidance of pain.

In cases, for example, in which there exists a

definitely tender scar on the sole of the foot it is but natural that the patient should commence to walk in calcaneus, in equinus, in varus, or in valgus, according as the scar is situated anteriorly, posteriorly, internally, or externally.

Under these circumstances the deformity can hardly be said to result in the first place from contracture, but from a voluntary contraction executed with the object of maintaining a certain definite attitude. In many of these cases, indeed, this attitude is not primarily the result even of muscular contraction, but rather of mere passive forces, the weight of the body acting down through an abducted or adducted leg resulting in a passive rotation inwards or outwards of the foot round its long axis. Such a position is, on account of the shape of the various articular surfaces and the points of insertion of the different muscles, one that is not easily realised by voluntary muscular contraction; by reason, however, of a certain amount of laxity of the lateral ligaments of the ankle and sub-astragaloid joints the passive force of the weight of the body acting through the foot against the ground can induce a considerable amount of such massive rotation of the posterior tarsus around its antero-posterior axis. Let the reader himself assume this position; during standing, the weight of the body will be found to maintain it; during walking, but a slight amount of muscular contraction will suffice to keep up the rotation during the period the foot is off the ground. As soon as the patient sits or lies down of course the passive force of the body weight ceases to act; but some additional factor seems to come into play, whether it be a reflex or some form of subconscious auto-

suggestion, which maintains the mal-position, and so in time leads to the production of a permanent club-foot; a result that cannot, I repeat, be explained wholly or satisfactorily by the theory of a mere persistence of a more or less naturally assumed position.

In other cases, where the deformity develops after a mere sprain or other form of slight local lesion, it takes origin probably from some similar set of circumstances, some more or less unconscious attempt to relieve or avoid pain, the patient instinctively commencing to walk on the outer border of the foot; in such cases, however, the deformity is more often equino-varus than pure varus. In some cases the contracture becomes complicated by the secondary development of retraction of muscles or of actual joint stiffness, but this happens less often than one might expect; I have seen cases of two years' standing without the slightest trace of such secondary lesions.

2. **Treatment.**—(*a*) *Psychotherapy.*—It is highly probable that no such cases would occur were there carried out always an efficient supervision of the position of the foot both during the period of the treatment of the original wound and also during the patient's first attempts to walk; were the least tendency to varus detected at once and corrected by careful re-education or by an appropriate alteration of the boot; were all incipient cases sent at once to special neurological centres for treatment by suggestion instead of being allowed to stagnate in the physiotherapeutic centres, where they simply become more and more possessed by the idea of their disability, where they have a bad influence on one another, and where, consciously or unconsciously, they come to imitate the various deformities and disabilities around them.

As a matter of fact all forms of physiotherapy are quite useless unless they are combined with or made a means of suggestive treatment, which alone is adequate in cases of pure pithiatism, and in such it almost always succeeds when properly used. Where there is an association of pithiatism with a local lesion that has resulted in a reflex contracture suggestion should also be regarded as the most important and essential part of the treatment. There is no doubt that in all cases of severe, old-standing contracture that have refused to react to all forms of mechanotherapy the general psychopathic element is almost always responsible for a considerable part in its production.

As regards the treatment of the contracture *qua* contracture, since all our classical methods of attacking it have so far failed, our latest methods as far as the indications for surgical intervention go are still tentative, still in the experimental stage.

(*b*) *Surgical treatment.*—Of course everyone commenced treating these cases along the traditional lines—correction under an anæsthetic, followed by two or three months' immobilisation in plaster.

It is necessary to insist at the outset that whenever in these cases an operation is performed it should always be followed by a course of suggestion and of physiotherapy, whereas treatment by these means before correction of the deformity would have been useless and sterile of results; with the foot in good position again they come to have a much more hopeful field of usefulness before them.

Everyone soon found out of course that relapse almost invariably occurred as soon as the plaster was removed. The cases in which after forcible correction

relapse was apparently prevented by the wearing of an appliance with elastic traction were merely cases in which correction could have been equally effected by the use of such an appliance alone. It is the rule, moreover, in such cases for the patient after such relapse to refuse all further treatment.

The next development of surgical treatment consisted in trying the effect of correction plus tenotomy, particularly of the tendo Achillis and of the tibialis anticus; in this way it was hoped that when after the removal of the plaster the contracture recurred it would have nothing to act on, and so would lose its force. Even after this procedure, however, relapse is to be feared, although in my opinion its constancy or frequency has been considerably exaggerated. Among my own cases, by following up surgical treatment by well devised and carefully supervised mechanical treatment I have had excellent results by combining transplantation of the tibialis anticus with elongation of the tendo Achillis. As regards the elongation, I have already described its technique (see page 348); that of the tendon transplantation is as follows:

An incision of about 3 to 4 centimetres is made at the level of the ankle joint along the tendon—always prominent in these cases—of the anterior tibial muscle; this should on no account be carried downwards towards the sole. The tendon is next displayed and detached from its point of bony insertion by the point of the knife passed between it and the internal cuneiform bone. The end of the tendon is then caught in a pair of Kocher's forceps and pushed obliquely downwards and outwards between the tendon of the extensor proprius hallucis and the neck

of the astragalus. In most cases it will remain and become fixed there without any need to suture it to the bone. Under these circumstances this muscle retains its flexor action, although this is weakened by shortening of the arm of the lever on which it acts, but loses completely its adductor action. I verified this very carefully, and it was clearly proved in two cases examined several weeks after the operation.[1]

In the slighter cases such a procedure will probably suffice, but I think it is wise in most to complete the operation by performing an arthrodesis of the calcaneo-cuboid and sub-astragaloid joints (see page 392). Such will by the time walking is recommenced effectually prevent any adduction of the fore-part of the foot, whatever traction be exerted on it by the tibialis posticus.

From the moment that the plaster is removed re-education in walking and careful mechanical treatment—both supervised by the surgeon who has operated—should be instituted; my practice is as follows:

The patient, his foot fixed in plaster in calcaneo-valgus, experiences great pain for two, sometimes for three days; to relieve this morphia is always necessary. He should remain in bed for a month, and for a fortnight after that should be made to walk about in the plaster.

At the end of this period the plaster is removed, the dressing changed, the stitches removed, and the patient encouraged to commence walking.

A comfortable boot with its sole raised along the outer border is always got ready in advance for the

[1] The tibialis anticus is best transplanted to the base of the 5th metatarsal in those rare cases where such an operation is called for.—Ed.

patient to wear as soon as he gets up; in addition to this general exercise of walking he is given regular daily exercises of flexion of all the joints of the lower limbs; when squatting with the heels together and the toes apart he inevitably flexes the ankle joint and tilts the os calcis into valgus.

The majority of the patients give no further trouble; they walk quite naturally at once, with the sole of the foot in contact with the ground. Some, however, whether through fear or habit, or because they have no desire to return to the trenches, still insist in walking not indeed in equinus or in varus but with the whole foot rotated inwards. This, however, is much more easily dealt with than true varus with flexion of the mid-tarsal joint; elevation of the outer part of the sole usually suffices to throw the foot into external rotation.

In addition, in such cases it seems to me to be wise to order a night shoe fitted with elastic traction to pull the foot into valgus and calcaneus, even in some cases to require the patient to walk in it for a few weeks.

All these details I see to myself; the patient does not escape to some department or centre over which I have no control. I have learned the necessity for this by experience. One of my patients—a very good patient, in whom I had obtained an excellent result—sent to a depot for the supply of an appliance came back to ask me why:

1. He had been told that, since the operation was incomplete, relapse was certain;

2. He had been treated by "mechanotherapy," with passive movements of flexion and circumduction of the foot.

He understood that the flexion exercises were all right, for I had explained to him, as indeed I do to all my patients, that the ankle joint remained intact and possessed a free range of movement ; but the circumduction disturbed him, for he had quite rightly understood that the object of the operation had been the complete suppression of this movement.

From that moment I have undertaken to fit these patients myself with a shoe, which costs 1 franc 50 centimes—a great saving to the State—and which is very light—of great benefit to the patient.

I have performed this operation sufficiently often, and I have studied its results in all cases after a sufficient lapse of time, to be justified in asserting that its functional results are good. There is no need to arthrodese the ankle joint ; the other joints remain firmly ankylosed ; it does not interfere in the least with walking, and it effectually prevents relapse of the deformity, so frequent after treatment by tenotomy. On return of the contracture it exhausts itself on an ankylosed joint, and so becomes ineffective.

E. Paralytic Deformities and Disabilities

Lesions of nerve trunks, whether partial or complete, anatomical or physiological, result among other things in paralysis, complete or incomplete, of those muscles whose motor nerves leave the trunk below the level of its lesion.

I do not intend here to deal with neurological surgery properly so called ; with the question of the possibility of correctly diagnosing the exact nature of the lesion ; nor with the special indications—which I suppose are always worked out in advance—for the performance

of nerve suture, of neurolysis or of simple exploration of the nerve trunk ; nor with the process and nature of regeneration. All these form the subject-matter of other special volumes of this series.

One aspect of regeneration, however, does very vitally affect us in this book. One knows that it eventually takes place ; one knows, too, that even under the most favourable circumstances it is inevitably slow, that it is quite impossible in any case to indicate even approximately the time necessary for its accomplishment. The age of the patient, the extent of the damage or loss of substance sustained by the nerve trunk, the time that has elapsed between the reception of the wound and the performance of the operation, the distance to be traversed between the point of injury and the muscle to be re-supplied, are known to be some of the factors involved, but there is no constant relation between any of these and the actual period of regeneration.

Is it right to conclude in the absence of recovery of the least amount of voluntary movement long months after the performance of the operation that such an operation has been a failure ? By no means, for during the whole long period occupied by the regeneration and growth of the new fibres no clinical sign of recovery is to be looked for, nor in the least expected. On the other hand, once the new fibres have succeeded in reaching their objective the whole phenomena of recovery may occupy but a relatively short period—a period sometimes to be measured in weeks. What is happening during the first of these periods—the period of regeneration—cannot be detected clinically nor by electrical examination ; we remain completely in the dark until the commence-

ment of the second period—the period of recovery. The onset of this second period is always sudden and without warning, and its duration correspondingly short.

It is important that the surgeon should realise this, otherwise he may be tempted under pretext of correcting a deformity or of reducing a disability to perform an operation that would forever render useless muscles that may for all he knows be within a little of complete recovery. I repeat, then, that the period of regeneration is not only long, but indefinite; we can at present fix no definite limit beyond which we can be certain that regeneration will not take place. This has a most important bearing on the treatment of paralytic club-foot.

The articular disability that results from division or compression of a nerve trunk differs according as all or only some of the muscles controlling the joint are paralysed.

In the former case the joint becomes completely inert, flail in all directions, moving in response to no law but that of gravity; in the latter, over-action of the unparalysed antagonists often results in the production of an abnormal and disabling joint attitude.

In the case of complete paralysis the joint is always at first, then, perfectly flail; the surgeon or patient can without any effort place it with the hand in any required position; when left to itself it simply falls back again into a position determined by its own weight. Such a joint may in time, however, become secondarily fixed in mal-position, either by the development of a bony deformity, the result of the persistent abnormal transmission of the body weight (the occur-

rence of even the slightest degree of this is rare in the adult), or by simple joint stiffness or muscular retraction (the occurrence of these is of course very frequent in war surgery); in either case the position of the joint becomes no longer capable of correction by simple manual force.

With the motor paralysis there co-exist in very many cases certain vasomotor and trophic disturbances; the existence of these should have an important influence in any consideration of the indications for surgical treatment. Fortunately, however, two of the most common of all peripheral nerve injuries, those of the musculo-spiral and of the external popliteal nerves, are associated with but very slight and unimportant disturbances of this sort. Along these two nerves, too, regeneration takes place more readily and more quickly than along any other of the peripheral nerves of the limbs.

The general principles of the treatment of such paralytic deformities and disabilities may be quite easily summarised as follows:

Where the joint is flail, the action of gravity should be overcome either by wearing an apparatus with elastic traction or by the performance of the operation of arthrodesis; this consists in such a removal of the articular cartilage as results in the production of an ankylosis of the joint.

Where certain muscles or groups of muscles remain unparalysed, treatment by tendon transplantation may supplant or supplement either of these two methods.

Where the joint is both deformed and fixed it becomes first of all necessary to correct this position, and after that to maintain the corrected position by one of the above-mentioned methods.

We will study the application of these general principles to three different individual cases : (*a*) circumflex paralysis or paralysis of the deltoid muscle ; (*b*) musculo-spiral paralysis, resulting in wrist-drop ; (*c*) great sciatic paralysis, resulting in either a completely flail foot or simply in a dropped foot.

Even in cases, however, in which one has good or fair grounds for anticipating the eventual occurrence of regeneration and recovery the patient should be fitted with supporting apparatus ; this for the following reasons :

1. In order to avoid possible fixation of the joint in a disabling or deformed position ;

2. In order to avoid stretching paralysed or recovering muscles ;

3. In order to avoid the results of possible contracture or retraction of unparalysed antagonists.

(*a*) *Circumflex paralysis.*—Although I have not as yet in war cases had occasion to operate for paralysis of the deltoid, I will devote some space to its consideration, because in the rare cases in which it is complete and final and unaccompanied by any osteo-articular lesion it possesses a definite surgical indication. In such cases the disability is practically identical with that of the flail shoulders that follow resection ; the weight of the limb, no longer taken by the deltoid, drags the humeral head down away from contact with the glenoid surface, and this in turn stretches and throws out of action the rotator muscles of the shoulder ; and as apart from the deltoid the power of active abduction, direct or oblique, is nil, a fixed point of support for the movements of the forearm and hand is absolutely lacking. Such a condition constitutes a worse disability than ankylosis of the

shoulder joint; indeed, often it forms a direct indication for the performance of arthrodesis of the shoulder joint. This should be carried out through an anterior incision identical with that for resection of the joint; through such it is a simple matter to remove the cartilage from the articular surfaces. I repeat that so far I have not had to perform this operation on a wounded soldier; but in cases of infantile paralysis, by its performance I have succeeded in obtaining for the patient both an efficient point of support for the forearm and a certain range of active abduction by rotation of the scapula. In order to regain such power of active abduction it is of course essential that the serratus magnus should not be paralysed.

Such a result is much better than that given by a mechanical appliance, which necessarily includes and interferes with the action of the elbow joint.

(*b*) *Musculo-spiral paralysis.*—A few words concerning this will suffice, for the opportunities that it provides for surgical intervention appear to me to be quite exceptional.

In musculo-spiral paralysis, when the forearm is pronated the hand falls into flexion; when, on the contrary, the forearm is supinated, the weight of the hand carries it back into line with the forearm. With the forearm pronated and the wrist flexed, the flexor muscles, their points of origin and insertion being thus approximated, are placed at a disadvantage, and so lose a considerable proportion of the strength of their contraction. In the opposite position of supination with extension of the wrist they regain the lost power; but it is precisely this position of supination with extension that in musculo-spiral paralysis the patient

is unable actively to maintain. Stiffness of the wrist joint in flexion is rare in its occurrence.

Two different types of operation have been tried to remedy this disability :

1. Transplantation into the back of the wrist, or anastomosis with the extensor tendons of the tendon palmaris longus. I confess that I have always had but little faith in the results to be obtained by such transplantation operations, in which is completely reversed the normal function of the transplanted muscle ; for example, in this case a flexor is turned into an extensor.[1]

2. The performance of arthrodesis of the wrist joint, in a line with the forearm, or better, in slight extension. Where one is certain that regeneration will not take place this is certainly an effective way of ridding the patient of an external appliance. But one should refrain from stiffening the wrist as long as there is the slightest chance of recovery taking place.

In almost all cases, then, the patient should be advised to wear a prosthetic apparatus. Of these there are two chief types :

The original, that on which many of the modern patterns are modelled, is that of Duchenne of Boulogne. It consists of a cuff or sleeve for the forearm, to the back of which is attached the upper end of small springs, which are fixed below to small rings encircling

[1] In the orthopædic centres in Great Britain we have found transplantation of tendons one of the most satisfactory operations, and, with a correct technique, very reliable. The palmaris longus unaided is not sufficient. We usually transplant the pronator radii teres into the extensors of the carpus, the flexores carpi radialis and ulnaris into the extensors of the thumb and fingers. The palmaris longus can be utilised for the thumb if preferred. The results of these operations are beyond question, and the patients require no apparatus when re-education is complete.—Ed.

the fingers. The second more modern type consists of a small anterior splint of the "cock up" shape, ending in a small palmar pad that serves to keep the wrist extended; this is much less cumbrous, lighter, and seems to serve its purpose quite as well. I may add that I have seen several patients with wrist-drop deliberately remove their apparatus before commencing their work; they are undoubtedly wrong to do so, but it at least suggests that they do not in every case find them of much practical use.

Where there exists a tendency to fixation of the wrist in flexion or of the fingers, with thickening and adhesions of the extensor tendon sheaths, the dorsal apparatus of the Duchenne type becomes necessary. A similar form of appliance is useful to prevent or overcome retraction of the little and ring fingers in ulnar paralysis during the period of regeneration, or in cases where, without actual paralysis, retraction of these fingers is threatening to occur. Where, however, all chance of regeneration of the nerve has disappeared —and unfortunately failure of regeneration of the ulnar nerve is not rare—the wearing of such an apparatus permanently is really more disabling than useful.

(*c*) *Great sciatic paralysis.*—The great sciatic nerve or one of its branches is very frequently injured anywhere along its course from buttock to calf; the external popliteal nerve is, however, much more frequently injured than the internal. Not only is this so below the point of bifurcation of the great sciatic (it is here more exposed to injury by reason both of its nearness to the surface and of its intimate relation with the head of the fibula in fractures of which it is commonly involved), but in the main trunk of the nerve itself the fibres of this outer

portion are much more frequently injured than are those of the inner part.

Hence we will concentrate our attention on the disability that results from division of the external popliteal nerve; the surgical problem presented by its paralysis is, moreover, simpler and less complicated than that of lesions of the internal popliteal nerve, in which in addition to the motor disability there exist circulatory and trophic troubles. We will study, then, the disability that results from complete division of the external popliteal nerve uncomplicated by any superadded joint stiffness.

Clinical study.—When this nerve is divided the following muscles are paralysed:

The tibialis anticus.—A strong flexor of the anterior tarsus; an adductor and internal rotator of the fore-part of the foot.

The extensores communis digitorum and proprius hallucis.—Both of which on completion of their action on the toes become feeble flexors and abductors of the foot.

The peroneus tertius.—A flexor and abductor of the foot.

Peronei longus et brevis.—Abductors; the longus in addition resulting in a lowering of the fore-part of the foot, and hence in an increase of the concavity of the internal arch of the foot.

The extensor brevis digitorum.

The unparalysed antagonists are:

The gastrocnemius and soleus.—Almost direct extensors of the ankle. These are the only muscles that act directly on the posterior tarsus.

The tibialis posticus.—An almost direct adductor of the fore-part of the foot.

The flexors of the toes.

All the short muscles of the sole of the foot.

Hence the foot, whether the patient be seated or recumbent, hangs down into a position of equinus, complicated by a certain amount of varus, with, in addition, slight flexion of the proximal phalanges of the toes. When the leg is shaken the foot dangles limply at its end.

Such attitude of equinus or equino-varus cannot be actively corrected by the patient; no active upward and outward movement of the foot at the ankle or mid-tarsal joints or upward movement of the toes at the metatarso-phalangeal joints is possible; the two distal phalanges of the toes can be weakly extended by the interossei. The opposite movements, on the other hand, can be actively executed, but result in an exaggeration of the mal-position of equinus (the increase in the deformity produced by their contraction is but slight, as the weight of the foot has already brought it well into equinus), in an increase of the amount of varus, and of the flexion of the toes.

Getting the patient to attempt all these movements singly and in turn is the only practically reliable method of determining which of the muscles of the leg remain unparalysed; in more cases than is often realised the case will be found to be atypical, not one of complete external popliteal paralysis, but of incomplete interruption by compression of the nerve by scar tissue, and very often complicated by a partial lesion of the internal popliteal nerve as well. It is now well recognised that of bullet wounds of the great nerve trunks of the limbs the majority are incomplete.

Although I have said that the fibres of the external popliteal nerve are the most exposed to injury, that is not meant to imply that the fibres of the internal always or altogether escape; these latter are often contused, torn, or compressed, so that a careful examination will show a symptom-complex indicating an incomplete lesion of both nerves, in which, however, the signs of external popliteal paralysis predominate. The same occurs in wounds of both nerves in the popliteal space. Lesions of the individual branches of the external popliteal nerve, of the anterior tibial, or of the musculo-cutaneous nerves are rare, and often difficult to distinguish from injuries and sclerosis of the corresponding muscular bellies.

Hence in all cases we should carefully investigate the two following points:

1. Whether there is complete paralysis of all the muscles supplied by the external popliteal nerve.

2. Whether there is any paralysis of muscles supplied by the internal popliteal nerve.

These points should be investigated by getting the patient to attempt in turn the particular action or movement normally performed by each muscle; not only should the actual movements of the foot be noted in response to the muscular contraction, but the tendon of each individual muscle should in addition be carefully palpated during its contraction; where two muscles perform the same action—for example, the two tibials are both adductors of the mid-tarsal joint—such palpation of the tendons singly and in turn becomes all the more indispensable.

The indications for surgical treatment. — The diagnosis having been established in detail, the indications for orthopædic treatment depend on:

1. Whether the deformity is a fixed one.
2. Whether, on standing, the sole of the foot comes into normal relation with the ground.

Indeed, the aim of all treatment of club-foot of whatever variety or origin may be said to consist of:

1. Full correction of the deformity; and
2. Maintenance of the corrected position so that the sole of the foot comes into normal contact with the ground during walking and standing. At the outset a "paralysed foot," which is not necessarily a "club-foot"—I will explain the difference later,—is a flail foot; in other words, it moves about, whether the patient be standing, walking, sitting, or lying, purely in passive obedience to the action of gravity and to the force of contraction of the unparalysed antagonist muscles; it dangles lifelessly at the end of the leg when this is shaken; from whatever position, it can always be passively brought to the normal without any effort of exertion being required.

Later it may become fixed in a position determined either by the contraction of the unparalysed muscles or simply by the action of gravity; such fixation is brought about by two factors acting singly or in combination:

1. A gradual deformation of bones and joints.
2. A retraction of muscles and ligaments.

In the case of club-foot the result of infantile paralysis, when the age of the patient allows of plastic modelling of the bones of the foot in accordance with new and abnormal lines of transmission of pressure, the former is a factor of the greatest importance. Certainly in such paralytic club-feet this adaptive process does not usually occur to anything like the same extent as it does in congenital club-feet;

but it is nevertheless always considerable. On the other hand, in such cases there is not so very great a tendency for the foot to be pulled by muscular action into varus and valgus ; such lateral deformity as exists, however, is always increased and exaggerated under the influence of the body weight during walking. In such cases, then, manual correction, even forcible, of the deformity is no longer possible ; a tarsectomy of greater or less extent becomes necessary before the bony obstacle is removed.

Such a state of affairs, however, is not to be expected in the case of the wounded ; they have passed the age when the bones are so exceedingly plastic. I have not as yet had to perform tarsectomy in any case of peripheral nerve injury in an adult. But in these cases the second factor, muscular and periarticular retraction, becomes of very great importance. In addition to the paralysis, such periarticular and muscular lesions develop as I have described at length already in this book ; and these become most marked in cases where the nerve lesion has resulted in vasomotor and trophic trouble.

Treatment will obviously, then, have to commence by dealing with these secondary lesions ; elongation of the tendo Achillis, followed by forcible correction of the position of the foot, will require to precede all other treatment. It will be equally obvious, however, that if treatment stops short at this, does no more than correct the deformity, relapse will almost certainly occur ; the disturbance of the muscular equilibrium still remains, and will tend to reproduce its former effect as soon as the plaster is removed from the foot.

Relapse, then, will occur in all but a few exceptional

cases in which the original stiffness has been of severe degree and necessitated the exercise of great force in the breaking down of the dense adhesions, so that a severe and painful reaction with much swelling and bruising results; such cases are very likely to become permanently stiff in the corrected position, so that in them no further treatment aimed at the prevention of relapse will become necessary, provided always that the varus element of the deformity has been completely got rid of, that the sole during walking and standing can be brought into normal relation with the ground. Under such circumstances the occurrence of stiffness should be regarded as a favourable event. It would no doubt be quite an easy matter to perform the operation of arthrodesis in all cases that present the mechanical indications that I am going to recount; but the problem is complicated by the frequent lowered vitality of the tissues of the foot, so that it often becomes necessary to restrict all operative interference to a minimum of what is absolutely necessary and not of what may be merely desirable. Such cases constitute a test of the surgeon's clinical tact and experience, to decide when to perform arthrodesis and when to be content with manipulation into good position, followed by the use of a surgical appliance. As we shall see, a similar alternative lies before us in considering the treatment of perfectly flail joints.

The flail paralytic foot is that which drops inertly into mal-position merely through its own weight, but which can be passively redressed into good position without any effort.

In such, a very simple clinical examination suffices to determine what steps, if any, are necessary to

maintain this good position. In order to decide this the patient should be examined lying down, standing, and walking; in this connection it should be borne in mind that a flail foot is not necessarily a club-foot.

A foot is to be regarded as a club-foot when the transmission of the body weight, active and passive, does not take place through the bony prominences of the sole in the manner described on page 269; when the foot is deviated either into valgus, the inner border of the foot transmitting the body weight along its whole length, the internal arch being flattened out by abduction and outward rotation of the fore-part of the foot, or into varus, the weight being transmitted through the outer border, the fore-part of the foot adducted and internally rotated. However, it is only the deviation into varus that concerns us here.

Now, in many of these cases, while the patient is standing at attention the sole of the foot retains a normal relation to the ground, since the slight inclination to valgus, due to the body weight acting on an arch already weakened by the paralysis of the anterior tibial and long peroneal muscles, counteracts any tendency to deviate into varus that may exist.

When, however, the patient commences to walk he always starts off with the paralysed foot, resting the whole of the body weight for the moment on the sound foot. By flexing the hip and the knee joints he lifts the foot from the ground, but at once, owing to the absence of all power of voluntary flexion of the ankle joint, it drops into equino-varus, so that when swung forwards the back of the toes are inclined to scrape along the ground. Whilst carrying the foot forward, then, the knee has to be sufficiently flexed

to clear the toes from the ground; then by a sudden jerk it is again extended, so that the ankle joint through the inertia of the foot becomes passively flexed. By a rapid and skilful performance of this steppage manœuvre the patient eventually manages to get the heel into contact with the ground. If during this stage the leg has been abducted and externally rotated, the tendency will be for the sole to come into contact with the ground perfectly normally or in very slight valgus, any varus deviation being thus counteracted.

Such correction of the varus tendency, however, does not always take place; in a considerable number of cases this element in the deformity persists whilst the patient is walking.

In many cases, provided the boot worn is sufficiently light, this steppage manœuvre serves the patient well; but it is essential that the boot be light, for all extra weight seriously hampers the patient. Especially in cases where there persists the slightest amount of power in the antero-external muscles of the leg can walking thus be effected unassisted by the performance of arthrodesis or by the wearing of an apparatus. Where a tendency to varus exists, however, the outer border of the boot should be raised.

Where there is absolute paralysis with a perfectly flail foot, however, something has to be done to assist the passive flexion of the ankle joint, and the surgeon has to choose between a special boot and appliance and the performance of an open operation.

1. The principle of the surgical boot with artificial muscles is simple and very easily understood. Two elastic tractors (of indiarubber or metal springs) are fixed below, one to each side of the fore-part of the

sole of the boot, and above to a metallic upright fastened into the leg piece of the boot; the higher this leg piece and metal support, the greater the force of traction on the foot exerted by the tractors. Where the two springs are of equal strength they result in direct flexion of the ankle joint. Any tendency to varus is corrected by (1) increasing the strength of the outer spring, and (2) by raising the outer border of the sole of the boot so that the foot is tilted into slight valgus. This thickening of the outer part of the sole from 5 to 10 millimetres, according to the case, should extend right along the boot, but should reach its maximum under the base of the 5th metatarsal bone. To effect this thickening the two layers of the sole should be unsewn and the thin wedge inserted between them and the whole resewn; in this way the boot will be light and neat, and the wedge remains concealed.

2. *Arthrodesis.*—Permanent fixation is effected surgically by the performance of the operation of arthrodesis. This consists in a removal of the cartilage from the articular surfaces of a joint, which immobilised in good position undergoes ankylosis or synostosis.

In order to understand the indications for its performance in connection with the joints of the foot it is essential to have a full and accurate knowledge of the anatomy and physiology of these joints (see page 266).

If permanent correction of equinus be desired, the ankle joint must be arthrodesed at a right or, better, at an acute angle. If we wish permanently to do away with a varus deformity, arthrodesis of the mid-tarsal and sub-astragaloid joints must be performed, and the foot fixed in a position of slight valgus.

In the early days of the performance of arthrodesis the ankle joint alone was fixed; but it soon came to be recognised that mid-tarsal and sub-astragaloid fixation was necessary if all tendency to relapse of the varus was to be avoided.

Now, in these cases it is the varus and not the equinus that is the chief element in the disability.

Hence, nowadays, we find that in most cases all that is necessary is the fixation of the sub-astragaloid and mid-tarsal joints, the ankle joint being left freely movable; and this for the following reason:

Where the ankle joint is ankylosed in good position the patient walks as on a peg leg, on the heel alone. This no doubt is a gain where all the muscles below the knee are permanently paralysed; but where some retain voluntary power, however slight, where a certain range of but weak active movement of flexion and extension of the ankle be possible, a stiff ankle joint is no advantage, is indeed a disability.

In these circumstances the mid-tarsal joint should be fixed so that, all deviation of the fore-part of the foot into varus or valgus becoming impossible, the former adductors and abductors, whether they remain strong or paretic, develop into direct flexors and extensors of the ankle joint; the tendo Achillis loses, too, all its adductor action. Direct active flexion and extension of the ankle joint thus remains free.

As a matter of fact this form of arthrodesis is much better suited to cases of external popliteal paralysis than to cases of infantile paralysis. Of course the surgeon should never lose sight of the probability or possibility of the occurrence of regeneration and recovery of motor power, and also such arthrodesis should never be performed until all has been done

in the way of neurolysis or nerve suture to favour the chances of such an occurrence. If and when recovery takes place, ankylosis of the mid-tarsal and of the sub-astragaloid joints will result in practically no disability at all, whereas ankylosis of the ankle joint would go very far towards rendering the whole laborious process of regeneration useless.

Most neurologists are agreed that it is quite impossible in any case of clinically complete division to decide by study of the signs and symptoms whether such division is anatomical or physiological, so that no indications for or against the performance of arthrodesis are to be gained from such a study.

The performance of arthrodesis of all these three joints in any one case is but very rarely indicated; this impossibility of foretelling definite failure of regeneration and recovery is the chief reason why I have always set myself against that procedure whereby the ankle joint is widely opened up, the astragalus temporarily dislocated, or even removed and replaced after a thorough stripping of its cartilage-covered surfaces; as also against those operations in which the skin and tendons in front of the ankle are cut across in order to give entrance to the ankle joint, even although they are subsequently re-sutured.

Such operations can of course lay claim to many successes; almost invariably, however, they end in ankylosis of the ankle joint, and absolute failures, and even catastrophes, are not infrequent. Only a few weeks ago a patient came to me with his foot blue, swollen, and fixed in varus, his toes powerless and retracted. There was nothing for the condition but disarticulation at the ankle joint—Syme's amputation—which I performed. He had been operated on some

time previously by quite a distinguished young surgeon for arthrodesis of the joints of the foot ; a transverse incision had been made, and the tendons in front of the ankle cut and re-sutured. From my examination of the foot after amputation, and also from the history, it was obvious that the resultant failure was not due to occurrence of sepsis ; I found, however, the extensor tendons adherent and bound down to the bone by a dense cicatricial mass, whilst of the joints the sub-astragaloid alone was ankylosed.

From my own experience I know that arthrodesis of the foot can be carried out quite well through a short external incision ; thus have I always performed it in children, and since the war in a fair number of adults.

Commence the incision at the anterior border of the external malleolus about 1 centimetre above its tip, and carry it down in a straight line to the most prominent part of the tubercle of the 5th metatarsal bone. This will be found to correspond to the upper edge of the tendon of the peroneus brevis. With the rugine now strip the ligaments and soft parts from the back of the tarsus, and also from the outer surface of the os calcis ; this can easily be done without cutting any tendon. By the use of retractors you will now be able to make out one finger's breadth behind the tubercle of the 5th metatarsal bone the white line of the articular cartilage of the calcaneo-cuboid joint. Two or three blows with the mallet on a wide but narrow-edged chisel held perpendicular to the bones will suffice to remove the cartilage with a thin layer of bone from the two surfaces of the joint. There will then come into view the line of the astragalo-scaphoid joint, which you will treat in the same way,

remembering that it occupies exactly the same transverse plane as the calcaneo-cuboid.

There is no need to spend much time in dealing with the anterior sub-astragaloid joint, for it is already opened into by removal of the head of the astragalus, the under surface of which resting on the sustentaculum tali constitutes the joint; a stroke or two with a sharp spoon will suffice to destroy what remains of its surfaces.

The posterior sub-astragaloid joint offers the greatest difficulty, as its surfaces are very close set; for this reason many surgeons hold that it cannot be effectively dealt with without temporary dislocation of the astragalus.

If, however, you force the foot well into varus and examine carefully just below the tip of the outer malleolus, you will be able to detect its slightly gaping joint space. This is narrow, but not too narrow to prevent you from removing the cartilage with a broad sharp gouge curved on the flat: Ducroquet has had a very suitable one made for the purpose. It is quite easy to do this even with an ordinary mallet and chisel, provided that it be remembered that the plane of the joint slopes backwards, inwards and upwards.

If in an exceptional case one has to ankylose the ankle joint as well, its capsule should be incised through the same incision, just in front of the fibula, and along its attachment to the front of the tibia; by retracting forwards the soft parts in front of the joint a sufficiently wide access is obtained to allow of the complete removal of the cartilage, either with a curette—starting with a small one—or with a hand gouge, or more simply with hammer and chisel.

Such a method of operating is not spectacular, but, as long as these details are carefully carried out, the desired end will be obtained without cutting any tendon or ligament of importance.[1]

Conclusion.—In any case of great sciatic paralysis, then, in addition to investigating and dealing with the state of the nerve itself it is of the utmost importance always, and as early as possible, to keep the foot in a good functional position.

In many cases no special treatment is necessary for this; the patient himself brings his sole into normal contact with the ground by the adoption of a "steppage" gait.

Where there exists, however, marked equinus, or the least tendency to varus, such should at once be corrected by the use of a special boot with a well-constructed sole, and fitted with elastic traction; this even in cases where one has good grounds for expecting successful regeneration and recovery. Under no circumstances should the patient be allowed to get about on crutches, his foot being allowed to deviate more and more into equino-varus, and to become increasingly stiff.

When the foot has become thus stiff, surgical intervention is necessary, but as long as the foot remains

[1] In paralysis due to lesion of the external popliteal we have found tendon fixation reliable and simple, and it allows movement from the right angle upwards. The foot is held just a little above the right angle, and an incision is made in front of the tibia a couple of inches above the annular ligament. The tendon of the tibialis anticus is divided and passed through a tunnel in the bone. Through the same tunnel may be passed the peronei tendons, which are first divided, displaced, and passed through the annular ligament; or the peronei may be divided and passed through the fibula. The foot is then slung to above the right angle, and the patient is enabled to walk without an apparatus. In complete sciatic destruction the tendo Achillis is divided in addition, and the lower end fixed into the back of the tibia. We prefer this operation to that of arthrodesis.—Ed.

flail the indications and counter indications for surgical treatment should be carefully weighed.

So long as the foot can be passively redressed into good functional position, and so long as there is still hope of the eventual occurrence of recovery, a surgical boot with elastic traction should be adopted. In this connection the long period necessary for the accomplishment of regeneration, and the uncertainty of the signs of its progress, should not be left out of account.

In cases complicated by the least amount of varus, however, the situation is quite different ; a foot fixed in varus cannot adequately be controlled by a boot or appliance. In such cases the performance of arthrodesis of the sub-astragaloid and mid-tarsal joints permanently corrects the varus, and at the same time does not in the least interfere with the patient's powers of walking.

Arthrodesis of the ankle joint—with it, it is always necessary to combine arthrodesis of the other joints as well—is only exceptionally indicated; it is to be performed only in cases with permanent paralysis of all the muscles below the knee. It is never indicated in cases of pure external popliteal paralysis ; whilst in complete division of the great sciatic or of the internal popliteal nerve, the occurrence of circulatory and trophic troubles render surgical intervention inadvisable.

CHAPTER IV

LESIONS OF THE BONY LEVERS: DEFECTS OF BONY UNION

Cases of defective union and mal-union in bones are among the frequent after-effects of gunshot fractures. Loss of bony substance of immediate or later occurrence, wounds of the soft parts preventing the methodical application of requisite apparatus, infection of the bone of a more or less chronic nature, are among the causes of the frequency with which are observed :

1. Mal-union, the result of overlapping or angulation of fragments.
2. The excessive production of callus.
3. Delay and absence of union.

In the pages that follow I shall not deal at all with infective complications, with chronic osteomyelitis, but shall concern myself exclusively with the three lesions here enumerated, *i.e.* with the mechanical results, with the late motor disabilities, of such fractures.

1. Shortening and Angulation of Fragments

Fractures, wherever they occur, become consolidated :

(1) By means of a cylindrical sheath of sub-periosteal bone, rapidly formed, and destined eventually to be partially or wholly re-absorbed. This is the "provisional callus of Dupuytren."

(2) By the intermediate callus, which is lasting, and becomes organised gradually beneath the support of the sub-periosteal callus.

These two formations vary in their importance and persistence, according as the fracture is in a good or bad position, or is infected or uninfected.

Let us take as the first point of comparison the case of a simple fracture without any displacement, or with fully corrected displacement. The sub-periosteal sheath of small volume is re-absorbed rapidly, and only the intermediate callus persists. The bone attains, almost without perceptible difference, its former shape, length, and structure. When the reduction is imperfect, it is, on the other hand, the sub-periosteal callus which becomes the more important, at times very markedly so. Indeed, if the displacement persists, the detached periosteal laminæ undergo an intense ossification so as to make up what is lacking in the attempt at union of the badly displaced fragments.

In the case of a simple lateral displacement, fig. 2 shows how the periosteal callus firmly re-establishes the continuity of the bony lever; this then becomes modelled, but only to a slight extent re-absorbed; the consolidated bone remains with more or less sharp angulation and thickened, but without shortening.

The method is the same if overlapping exists, *i.e.* elevation of the lower fragment alongside the upper, to which it remains parallel (fig. 3). But the fractured surfaces here have lost all contact. Only the denuded

surfaces of the shaft touch each other, without, however, giving support to the axis of the limb; hence the intermediate callus is slow in formation,

FIG. 1.—Sub-periosteal callus in a fractured femur (child) without displacement, and of one month's standing; the space between the fragments is well shown.

FIG. 2.—Callus produced from the periosteum which has been stripped in the direction of the displacement; fracture with complete transverse displacement but without overlapping of the fragments.

and very slow in reaching strength sufficient to withstand pressure in the long axis of the limb; the callus is exuberant—it may end by being double the thick-

ness of the former bone—for a long time, if not for good; it is chiefly subperiosteal, and shortening is inevitable (fig. 4).

By angulation of fragments the direct transmission of pressure from one fractured surface to the other is still more interfered with. The principal rôle is played, both originally and ultimately, by the mass

FIG. 3.

FIG. 4.

FIG. 3.—Fracture with transverse displacement and overlapping of fragments. The callus has been produced by the periosteum, which has been stripped from the shaft on one side only (fig. 4).

In these cases, despite the slight degree of calcification that the relative transparence of the callus indicates, union was sufficiently firm to allow of walking.

of sub-periosteal bone which grows in the area of the angle formed by the two fragments; the bone, when finally united, remains crooked, the seat of union is always considerably thickened, and shortening of the limb is inevitable (fig. 5).

These two displacements are frequent, and it should be recognised that this fact has a direct bearing on the problems of treatment. It is certain, however, that they are often inevitable, the severity of the

immediate infection and the extent and position of the wounds having made the proper application of splints difficult, both in the early and in the later stages of treatment.

FIG. 5.—Union with marked displacement and angulation of the fragments of the femur.

The mechanical effect of angulation is twofold: not only is there diminution in the functional length of the limb, even in cases where the two fragments have not overlapped, but in addition such an interference with the normal range of movement of the

joint below the fracture, as I will explain in detail further on (*vide* page 407).

In war surgery, especially in the case of the femur,

FIG. 6.—Fracture of the femur, with shortening due to neither angulation nor overlapping, but to actual loss of substance. The bullet has been broken up into fragments.

whatever care may have been expended in the mechanical treatment of the fracture, real shortening, not due to overlapping or angulation, occurs with peculiar frequency. We can do nothing, in fact, for the often considerable space left by a loss of bony substance (fig. 6). The consequences of such bone

loss differ according as to whether there exists in the same segment of the limb an unfractured companion bone (as in the forearm and in the leg) or not (as in the thigh and in the arm). I shall deal first of all with such loss in the humerus and in the femur.

Let us suppose in one of these bones the loss of a whole segment of the shaft. Where the periosteal sheath has been sufficiently spared by the trauma and has retained its vitality, repair takes place by periosteal osteogenesis. But if the limb had been left to itself, the contraction of the long muscles would inevitably effect the elevation of the lower fragment into contact with the upper, so that a considerable shortening would result. Such a tendency we overcome by means of continuous extension, realising, however, that there exists a limit to such an action: it is on that account, in my opinion, wise to preserve whenever one can a longitudinal guide or support to the periosteal sheath by respecting at the primary operation all adherent fragments of bone, and by refusing to be in too great a hurry to remove sequestra; as long as these latter are not completely free, new bone is laid down around them to an extent much greater than is usually believed.

In this connection we should note a difference between shortening of the humerus, which, provided that sound union obtains, is of but little functional significance, and shortening of the femur, which, when it exceeds 4 centimetres, constitutes a disability both in walking and in standing, and one that interferes with the equilibrium of the pelvis and spinal column. In these days it is not rare to meet with cases in which the shortening from angulation and

overlapping amounts to 10–15 centimetres, or even more.

Where the fracture has soundly united, shortening of one of a pair of bones taking place in the lower part of the segment of a limb results in a deviation of the hand or the leg below the fracture towards the shortened bone. This is what occurs, for example, in the case of the fibula after a badly reduced Dupuytren's fracture, although this is the only case in which a fracture of the fibula has such an effect ; in fractures through the middle of its shaft the tibia prevents

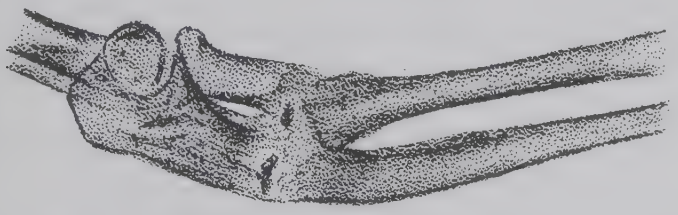


FIG. 7.—Fracture of both bones of the forearm united in pronation, and with synostosis of the radius and ulna and sequestra. Wounded 26th January 1915 ; date of radiogram, 17th February 1916.

displacement and acts as a splint ; every one is familiar with the subluxation of the upper end of the radius or of the fibula that may follow a fracture, with shortening of the upper third of the ulna or of the tibia respectively.

Synostosis of two such neighbouring companion bones, although of no practical importance in the leg, results in the forearm in a serious disability that we have already studied (page 287).

When a loss of substance occurs of one of such a pair of bones, the other prevents the elevation of the lower fragment into contact with the upper ; and although periosteal osteogenesis occasionally

proves capable of bridging the gap, yet this remains one of the commonest causes of pseudo-arthrosis.

In the shortening of the lower limb due to actual loss of bony substance, whether of the femur or of the bones of the leg, our only resource is a surgical boot with a thickened sole; in connection with this I re-insist on what I have already said on page 276: that as far as possible the patient should be made to walk with the sole horizontal, despite the fact that the boot looks less inelegant if the heel alone be raised and walking takes place in equinus. Where the shortening, however, is less than 3–4 centimetres, correction may be limited to the addition to the heel only of a thickening that corresponds to half the amount of shortening.

Since the war there has come into use for cases of extensive shortening an arrangement that allows an independent thick cork sole to be fitted to any shoe; hence a remarkable economy, since with a single cork sole one can wear out several cheap shoes, surgical boots properly so called which require frequent repairing being always expensive.

In civil surgery a remarkable elongation of a limb shortened by overlapping of the fragments of a fractured femur can often be effected by an oblique osteotomy through the original line of the fracture followed by continuous extension. Even if the fracture had been complicated by infection—which is quite exceptional—the suppuration has almost always been but slight, union has taken place quickly and well; there is but little chance of any recrudescence of the infection. In war surgery I have already said that things are very different; operation should be considered only in cases where the shortening is

considerable, and even in such cases most surgeons are inclined to abstain from intervention.

It has been proposed to remedy the mechanical disability of a short leg by resection—which should of course prove aseptic—of the opposite femur; this practice, however, does not seem to have attracted many supporters.

Shortening from angulation of the femur may likewise be improved by osteotomy. I have performed it but once in a case of truly enormous shortening (see page 284). Osteoclasis may be compared with osteotomy, but it has not been proved that recrudescence of microbic activity is any less frequent after the former than after the latter.

2. The Effect of Mal-united Fractures on the Action of Neighbouring Joints

I have thought that it would be useful to group together in this chapter certain rudimentary principles with which we are concerned in the study of the normal and pathological mechanics of the bones and joints.

Whenever, after the union of a fracture, the working of a neighbouring joint is interfered with and the range of its movement limited, it is usual to diagnose "ankylosis of the joint." When it is clearly established that the normal range of movement of the joint is definitely limited, such a diagnosis is of course quite correct. This does not, however, necessarily imply that the joint itself has lost anything of its potential former range; as a piece of mechanism it often remains in itself perfectly normal, nevertheless its physiological action has become abnormal; and

in order to restore in such a case the previous range of function, the surgeon has to deal not directly with articular structures, but with a pathological condition that is completely extra-articular.

The rationale of such articular disabilities following fractures is really much less difficult to understand than "mathematico-phobes"—so numerous among medical men—seem to think; these disabilities are due to the displacement *en masse* in any direction of a joint that in itself remains perfectly normal. From this there necessarily results a displacement or change of its field of action which is increased in the direction of the articular displacement, diminished in the opposite direction; and the physiological problem before us is to ascertain in each case in what way such a change will affect the usefulness of the limb.

A joint may be regarded schematically as composed of a fixed rod (in the limbs always the upper bone or bones) with which articulates a lower movable lever. These, like all solid bodies, bear a definite relation to the three primary planes of space:

(1) The vertical transverse,
(2) The vertical antero-posterior, and
(3) The horizontal.

These are the geometrical terms which correspond to the anatomical:

(1) The frontal plane,
(2) The sagittal plane,
(3) The horizontal plane.

Since in anatomy the body is always regarded as vertical, the upper limbs hanging in complete supina-

tion and the long axis of the foot in the sagittal plane, we must regard this schematic joint that we are about to study as being similarly placed, *i.e.* with the axes of the two levers (the fixed and the movable) both in the sagittal plane, and the transverse axis of the joint between them horizontal. This, then, is the position of the axes of the schematic limb in repose, the movable lever lying in the position from which it starts its movements, whose range may be measured in degrees, and which we may call flexion and extension in the sagittal plane, adduction and abduction in the frontal plane, rotation in the horizontal plane around the long axis of the limb, which remains vertical.

Now when this joint is displaced in its relation to the rods by a kink or bend occurring in one or other or both of these its axis undergoes a change of plane. From such a displacement *en masse* of the joint itself, unaccompanied by any change in the articular elements or in the actual range of its potential movements, there results a change to new planes of movements of the rods themselves, and the practical question that arises is to determine accurately under what conditions these modifications of the action of the joint limit movement in useful directions, thereby diminishing the functional utility of the affected joint.

I will take as an example the simplest case, that of a hinge joint represented graphically by a transverse bolt at right angles to the two articulating rods, one mobile the other stationary. Using the arbitrary positions in space that we have adopted, we see that this joint possesses but the movements of flexion and extension. It is the type of the knee and elbow joints.

The most complicated form of joint, from the point

of view of planes of movement—the ball-and-socket joint—possesses movements in every direction, including that of rotation. Of this form the hip joint is the type; we will study it later, especially in its relation to the movement of rotation and the analogous movements of pronation and supination.

A. The Effect of Mal-union on Hinge Joints

Suppose A B C to be a hinge joint, with C B fixed and movement of A B round B taking place

Fig. 8.

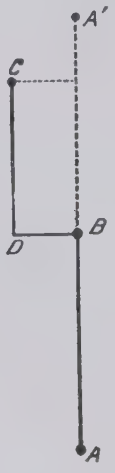


Fig. 9.

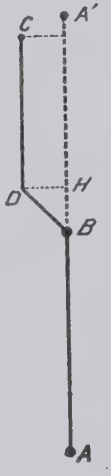


Fig. 10.

forwards only. The point A turning round the point B describes the circumference of a semicircle, ending by becoming superimposed on the point C, having passed through 180°.

These two lines C B and A B determine a plane in which this movement of A B takes place. Let us regard this plane as coinciding with the sagittal plane of the body, and then see what takes place when the

joint is displaced *en masse* by a kinking of B C. First in the frontal plane, second in the sagittal plane, and third in the horizontal plane. From the study of these the consequences may be readily deduced when the bending of B C takes place not in one but in simultaneous combinations of these three planes.

(*a*) *Transverse displacement of the joint* or displacement in the axis of the joint itself by angulation in the frontal plane of the fixed rod B C at the point D, forming either a right angle (fig. 9) or an obtuse angle (fig. 10).

Displaced thus, though unchanged in itself, the joint has lost its former axis with reference to the fixed rod C D. Its plane of movement will always be sagittal, but will now correspond to the line A B and no longer to the line C D. The super-position of A and C is now no longer possible; the point A will always be separated from C by a distance equal to that of D B. Hence we have displaced by this distance inward or outwards, to the right or to the left, the plane of movement of the joint, and whenever A B is flexed to 180° the point A will coincide with the point A′ along the prolongation of the line A B.

Where D B is oblique and not at right angles to C D, the amount of displacement of the plane of joint action will correspond to the projection D H (fig. 10).

The amount of this displacement is independent of the distance from the joint of the point D of bending, independent also of the length of the movable lever.

The range of movement—flexion—possible also remains unchanged, as the lever A B can still pass through 180° to take the position B A′.

In normal anatomy one sees this phenomenon exemplified, in relation to flexion and extension of the

hip joint, in the angle that exists between femoral shaft and femoral neck.

Here the neck is doubly oblique, and the plane of the displacement correspondingly so, but the mechanical principle remains the same. The movements of flexion and extension of the shaft take place not in the sagittal plane of the femoral head, but in a sagittal plane some distance external to it: this does not at all affect the relative range of flexion and extension of this joint, but other things being equal and in accordance with a mechanism that I shall describe for sagittal displacements, it adds to the field of adduction at the expense of that of abduction.

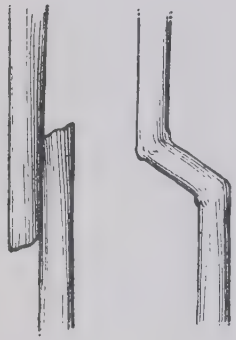


Fig. 11.

In the pathological condition of fractures a similar phenomenon occurs in those transverse displacements, in the extreme form of which the lower fragment slides up to lie along one or other side of the upper; the longitudinal axis of this lower fragment is thus displaced sideways to the extent of its own thickness; an analogous but rare state of affairs arises when in a double fracture the middle fragment lies more or less obliquely, so that the whole doubly bent lever becomes bayonet-shaped (fig. 11).

In such cases the amount of the displacement is small and of but little practical importance; what is important in such cases is the shortening that has taken place.

(*b*) *Sagittal displacement of the joint, or displacement parallel to the axis of the joint.*—Let us refer again to our diagrammatic articulation, let us con-

ceive the fixed limb as bent at D to an obtuse angle α, which lies on the side of the two levers opposite to that on which movement of the joint takes place, and the new axis B D as prolonged to B A downwards from the bend at D (fig. 12).

The joint B in itself has undergone no change, but in relation to the axis C D it has moved to the extent of the angle α.

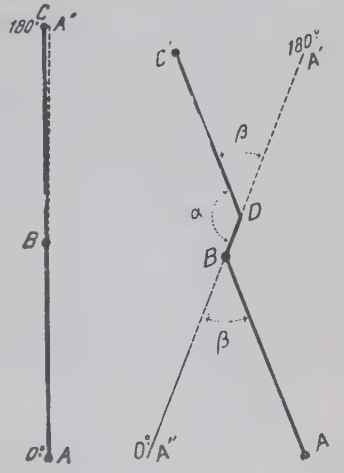


FIG. 12.

The position of A″, the new starting point of the movement (0°), is that where the rod A B lies in a straight line with B D; the end position of movement (180°) is that where B A′ is superimposed on the prolongation of B D, but this remains separated from D C by the angle β, the supplement of the angle of bending α. The range of movement remains unaltered in relation to the real axis B D, but in relation to the axis D C it has increased in one direction and towards one limit of the 180° of range, *i.e.* towards A″, and decreased to a corresponding amount at the other end, *i.e.* towards C′. Now if movement within the field represented by the angle A′ D C is functionally important, and in the field represented by the angle A B A″ of no practical use, the net result is a clear decrease of the range of usefulness of the joint.

This loss is directly proportionate to the distance which still separates the free extremities of the two

articulating rods when movement towards each other has come to an end. Hence it is greater the nearer the bend or kink is to the point of articulation.

With the angle C D A′ equal in both, the triangles C D A′ are similar; hence the longer the side C D, the longer also in proportion will be the side C A′ (fig. 13).

This geometrical diagram may be applied exactly

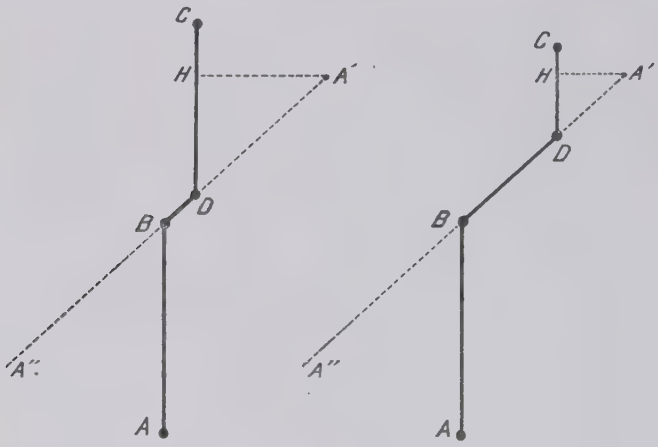


Fig. 13.

to our hinge joints, of which the best example is the elbow, when a transverse fracture of the lower extremity of the humerus unites at an angle with persistence of the backward tilting of the lower fragment.

In the elbow, normal flexion has a range something short of 180°; it is limited by contact of the soft parts of the forearm and arm. Functionally, however, flexion should be regarded as complete only when the patient can scratch the front of the shoulder with the tips of his fingers; if the flexion falls short of this, we should diagnose a limitation of the full functional

capacity of the joint, and technically the condition becomes one of ankylosis. The joint itself, however, remains quite intact and normal, but its movements, still of a potentially normal amplitude, have lost some of their functional usefulness, which exists only in relation to the long axis of the humerus ; they are increased in the direction of hyper-extension of the joint, an increase of no functional significance whatever ; they are decreased in the direction of flexion—a most prejudicial decrease from the functional point of view. In other words, flexion has been handicapped from the commencement, and by the time movement is complete it has not made up its handicap.

The typical case often met with is that in which, the joint remaining normal in itself, careful clinical examination establishes the existence of a negligible degree of hyper-extension. But if because of some additional articular lesion extension also is diminished, that does not of course alter the diminished flexion. The paradoxical condition may even occur in which, the forearm at the full limit of its extension lying in a line with the long axis of the arm, extension although practically normal is yet mechanically diminished (by articular lesion), whilst flexion mechanically normal (unaffected by such articular lesion) yet practically falls short of the normal.

The same thing happens in cases of Colles's fracture of the lower end of the radius, in which union has occurred with persistence of the backward tilting of the lower fragment, giving rise to the so-called " dinner-fork " deformity.

The normal movements of the hinge joint of the wrist take place in the two directions of flexion and extension in relation to the long axis of the forearm ;

the point of commencement of both these two movements—the position of zero in the geometrical scale of these two movements—is the position in which the long axis of the hand lies in the direct prolongation of the long axis of the forearm. If, then, the lower fragment has united in a position of backward rotation round the transverse axis of the fracture, *i.e.* slopes backwards and downwards when the long axis of the hand lies in the line of this fragment of the radius, it will make with that of the forearm itself an obtuse angle open behind; this constitutes an attitude of extension, the degree of extension being proportionate to the supplementary angle of this obtuse angle; consequently, unless the wrist joint by an increase in its suppleness extends its normal range of movement, flexion will to a corresponding degree fall short of its normal.

In this fracture, the radius being shortened because of the impaction whilst the ulna retains its full length, it is the rule for the hand to become displaced outwards into abduction; the range of abduction is thus increased, and that of adduction diminished; but there is, in addition, a horizontal displacement due to an inclination of the normal axis of the joint. Such will be considered later.

We have described, as regards these displacements, their usual form in each fracture, that of backward tilting of the lower fragment towards the direction of extension of the joint.

Exceptionally in the case of the radius, very rarely in the case of the humerus, union occurs with the lower fragment tilted forwards in the direction of flexion; in such cases the range of flexion is increased and that of extension diminished.

Such a state of affairs occurs in certain fractures of the lower third of the leg where union has taken place at an obtuse angle open forwards, the lower fragment sloping obliquely downwards and forwards. In such circumstances, with the foot at right angles to the leg and the knee straight it becomes impossible to plant the sole flat on the ground; when the femur and upper fragment of tibia are vertical

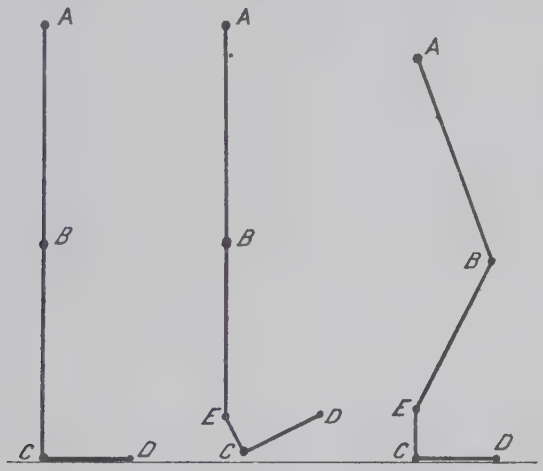


FIG. 14.

and the heel on the ground, as long as the ankle joint is held at a right angle it is quite impossible for the sole to come into contact with the ground, and the patient has inevitably to walk on the heel unless he resorts to one or two possible methods of compensation, either to flex the knee and then of course the hip (fig. 14), or else to drop the foot into a position of equinus, the latter method, however, limiting to a corresponding degree the natural rolling of the sole of the foot on the ground during walking.

Union in the opposite direction, the lower fragment

obliquely sloping downwards and backwards, sometimes happens, in which case, when the foot is at right angles to the leg and the fore-part of the sole on the ground, the heel remains in the air and the foot in a position of equinus, although the range of flexion of the ankle joint still remains normal. Slight cases of this disability in the absence of any articular

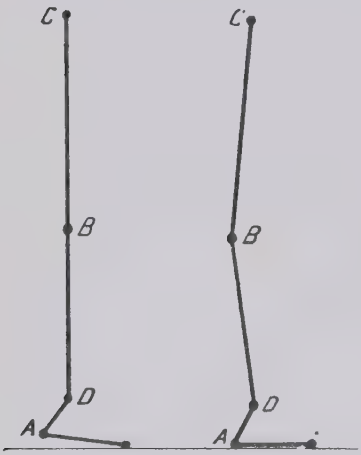


Fig. 15.

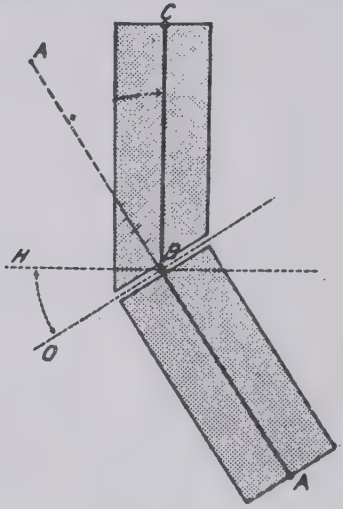


Fig. 16.

lesion gradually develop an increased range of flexion of the foot, which thus compensates for the limitation of flexion we have just described. In severe cases either the patient has to walk on the fore-part of the foot, which, unless compensated for by the existence of some shortening of the limb, is most inconvenient and awkward, or else he develops a progressive hyper-extension of the knee joint, which, if he persists in walking with the sole flat on the ground, in the end becomes a real compensatory genu recurvatum (fig. 15).

(*c*) *Horizontal displacement* by an abnormal inclination of the axis of the joint.

The joint A B C is viewed from the front and represented in its breadth so as to show the obliquity of the axis; the lever A B must always move at right angles to this axis, hence, this axis being oblique, it moves obliquely in relation to the bar B C. The plane of movement hence is no longer sagittal, and on flexion the point A comes to lie at the point A′ away from C on the side opposite to that to which the obliquity of the articular axis has displaced the free end A of the lever. The angle of deviation of the lever A′ B C is equal to the angle of deviation of the articular axis H B O. The absolute amplitude of the displacement (A′ C) depends on the length of the lever (fig. 16).

This case is not, then, an example of a simple angulation of the bone, but that of an elongation of one side of the fixed bone lever, the other side retaining its original length. Such a state of affairs occurs in supra-condylar fractures of the humerus united in varus; in such, flexion of the elbow joint, often of normal range, carries the hand well to the outer side of the shoulder, and the hand approaches the mouth only by a combination of abduction with internal rotation.

B. The Effects of the Mal-union of Fractures on Ball-and-socket Joints

The hip joint is an example of a ball-and-socket joint which not only allows of movement in all directions, but also permits, by an association or combination of these various movements following one another

in rapid succession, the further complex movement of circumduction.

(*a*) By reason of the angle that exists between the femoral neck and the femoral shaft the hip joint is, so to speak, displaced inwards ; and since the neck of the femur slopes downwards, outwards, and slightly

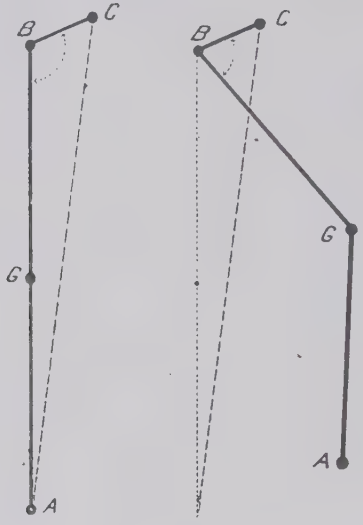


FIG. 17.

forwards, the effect of this displacement is correspondingly complex.

The mechanism of this joint may be easily understood if one considers the movement that takes place in each plane as the movement of a hinge joint. As these planes are, for flexion and extension the frontal plane, and for adduction and abduction the sagittal, one will readily comprehend that this natural displacement of the joint places a slight handicap on flexion—normally so important a movement of the joint—and a great handicap on adduction.

Any decrease, then, in the femoral angle at B will displace the shaft further into adduction, consequently will diminish the range of abduction. Every increase in this angle will have the converse effect (fig. 17).

(*b*) As regards rotation, let us commence by studying its effects in the case of a straight lever.

Suppose we erect a vertical axle rotating on pivots at its two ends, one of which rests on the ground. Regarding this as representing a human limb, and as standing in the sagittal plane, let us fix to each end of it half a crossbar, each of which also occupies this plane, so that the whole (leaving out of consideration for the moment the femoral angle) represents a lower limb, and the lower half crossbar, resting on the ground, the foot.

Suppose now we cut this axle across at any point between the level of its two crossbars and rotate the lower segment a slight distance round its vertical axis and then rejoin it to the upper in this new position; now, whenever the upper crossbar lies in the sagittal plane at the position of 0°, the lower will make with it an angle proportional to the amount of the rotation either inwards or outwards, and in whatever direction and to whatever extent the whole be now rotated, this constant angle between the readings of the degrees of rotation of the two crossbars will remain.

Such a condition as is here represented sometimes actually occurs in fractures of the femoral shaft that have united with but little or no overlapping, but in which some passive external rotation of the lower fragment has been allowed to persist uncorrected. If in such a case the amount of internal rotation possible at the hip joint still allows the long axis of the foot

to occupy a plane a little internal to the sagittal, the functional disability that results is of little practical importance; even where the ability to rotate the leg and foot inwards is lost—in other words, where the long axis of the foot can just reach without passing the sagittal plane—the disability remains still practically negligible. In extreme cases, however, in which the long axis of the foot, with as full internal rotation at the hip joint as possible, fails to reach the sagittal plane, the functional result is one of grave disability. In the first case the displacement of the lower fragment, and hence of the leg and foot, into a position of external rotation is less than the normal amount of full internal rotation at the hip joint; in the second case these two—the external rotation at the seat of fracture and the full normal internal rotation at the hip joint—are equal; in the third case the latter is less than the former, and a mathematician would say that the amount of internal rotation was a negative quantity.

(*c*) So simple and uncomplicated a displacement as we have here used as an example occurs but rarely; the displacement is usually a much more complex one, and takes place in all three of the primary planes.

Other things being equal, the functional consequence of such a displacement in rotation does not vary with the height of the mal-union; on the other hand, the higher up the femoral shaft towards the hip joint union with angulation takes place, the more serious the limitation of the range of abduction and adduction, and such angulation is the more likely to occur the higher the seat of fracture. The extreme cases of such displacement with angulation are usually subtrochanteric fractures.

If such fractures be left to themselves and neglected, without considering for the moment the element of the deformity due to the overlapping of the fragments, the shaft will be found to unite at an angle in the following manner : the upper fragment becomes flexed and considerably abducted, and slightly rotated outwards ; below it the lower fragment falls passively into a position of external rotation, and sometimes of adduction as well. That is to say, that on the occurrence of union the fragments will form a considerable angle, open inwards, and when the limb comes to hang vertically, parallel to its fellow, as long as the pelvis is kept symmetrical as regards the three planes of space and the upper fragment like that of the opposite side occupies the sagittal plane, the lower fragment of the femur (and consequently also the leg and foot) is in a fixed position of adduction and external rotation, and sometimes too in slight extension.

If the pelvis remained immobilised one can easily see that such a displacement would result in the limitation or total suppression of the range of abduction and of internal rotation. These movements should be regarded as non-existent when the axis of the limb in the case of abduction, the point of the foot in the case of internal rotation, fails to reach a vertical line passing through the head of the femur. Sometimes even such a mal-union affects the range of adduction, a disability which cannot be rectified except by compensatory tilting of the pelvis.

It is by a process of pelvic tilting, similar to that occurring in cases of ankylosis of the hip joint in malposition, that compensation for such limitation of the range of these movements is brought about, elevation

of the corresponding side of the pelvis in the case of the adduction of the limb, rotation towards the sound side in the case of the external rotation. Hence will be readily understood the functional gravity of these cases in which not only is there absolute loss of abduction, but even negative abduction, *i.e.* persistence of adduction of the limb when abduction at the hip joint has reached its limit. Correction of such adduction can be brought about only by a tilting of the pelvis, a procedure that merely adds an apparent shortening to the real shortening already existing, and always considerable in such cases.

(*d*) Such are the mechanical consequences of malunion of fractures of the shaft of the femur, regarded from the point of view of the movements imparted to the lower limb from the hip joint. Let us now study those of fractures of the femoral neck, *i.e.* of the part of the femoral lever that lies proximal to its normally existing angle. I have already shown how the diminution of the femoral angle (a rare condition) affects the range of abduction and adduction.

In cases of extra-capsular fracture of the neck with impaction, another variety of displacement of the lower fragment occurs, that of rotation with change of relation between the axis of the great trochanter (and hence of the femoral shaft) and that of the femoral neck.

If one looks perpendicularly downwards on to the upper end of a normal femur there will be seen a bar of bone expanded at its two ends, one forming the femoral head, the other continuous with the femoral shaft; this is represented in the diagram (fig. 19) as a straight linear axis.

In extra-capsular fractures the neck becomes im-

pacted into the posterior part of the great trochanter; the posterior surface of the neck thus becomes shorter than the anterior, so that the cervico-trochanteric axis becomes concave backwards, as represented in diagram 19—a curved axis.

Let us now consider the mechanical results of this change. The movement of rotation of the femoro-tibial lever does not take place round the longitudinal axis of this lever, but describes an inverted cone around the imaginary line passing from the head of the femur to the point of the heel; that is to say, that rotation on the heel corresponds to a movement of the neck around the head, the great trochanter describing in a horizontal plane the circumference of a circle of which the neck forms the radius; the position of commencement of the movement—the 0° of the scale of rotation—should be considered as lying a little in front of the frontal plane passing through the femoral head, since in the unrotated position—the long axis of the limb being in the sagittal plane—the neck slopes obliquely downwards, outwards, and forwards. During internal rotation of the limb the great trochanter moves inwards and forwards from this point, conversely during rotation outwards it passes outwards and backwards (fig. 18).

Let us now conceive the neck of the femur as bent to form an obtuse angle open backwards; this will, then, place the great trochanter behind the prolongation outwards of the femoral head. This means that when the articulating end of the lever is in a position midway between internal and external rotation—the 0° of the scale of rotation—its free lower extremity is displaced into external rotation. Hence in proportion to the amount of this displacement the range

of external rotation is increased at the expense of that of internal rotation, which is thus diminished,

Fig. 18.

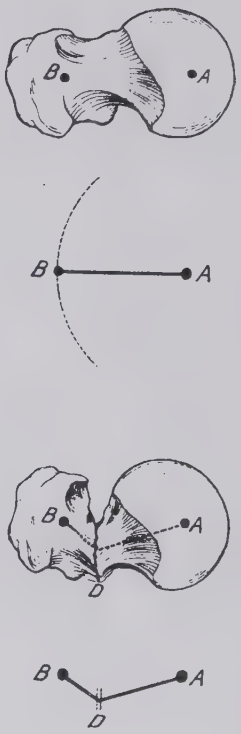


Fig. 19.

suppressed altogether, or even becomes a negative quantity.

(*e*) *The effects of mal-united fractures of the humerus on the range of movements of the shoulder joint* are from the practical point of view of but little importance.

In connection with such cases of mal-union of humeral fractures, which of course are far from uncommon, it is obvious that :

(1) Union with acute angulation of the humeral shaft outwards (a frequent variety) and inwards will diminish respectively the ranges of abduction and of adduction.

(2) Union with acute angulation forwards and backwards will diminish respectively the ranges of flexion and extension.

(3) Union with rotation of the lower fragment in one direction around its longitudinal axis will diminish the range of rotation of the shoulder joint in the opposite direction.

All these disabilities, however, on account of the compensatory movements of the scapula that come into play, have but little functional significance, and are on the whole negligible.

If the scapula be fixed quite firmly and the humerus moved through its range of pure abduction in the frontal plane, this will be found to stop short before the arm reaches the horizontal ; but when the movements of the scapula are no longer restricted, this bone tilts and so allows the humerus to reach—and even in young people to pass beyond—the vertical position. As there is normally no interference with this free range of movement of the scapula—the clavicle does not in the least restrict its power of increasing the range of movements of the shoulder joint—it will be readily understood that the loss of some degrees of abduction at the shoulder joint becomes hardly appreciable. The same applies with equal truth in the case of the movements of flexion and extension of the arm.

(*f*) *Mal-union of the radius and ulna resulting in limitation of the range of supination.*—Without entering into a full discussion of the details of the question—still a vexed question—of the movements of pronation and supination, we may say that the movement of pronation from the position of full supination consists of a rotation around its vertical axis of the upper end of the radius on the capitellar surface of the external humeral epicondyle, whilst at the same time the lower radial extremity describes a semicircle from without inwards round the ulna (which, however, also undergoes a movement of its own).

In cases of complete fracture of both bones the instinctive position assumed by the patient if left to himself is one of slight flexion of the elbow joint, with the palm of the hand resting either on the bed alongside the body (the hand being in complete pronation) or else on the abdomen (with the hand in semi-pronation). Now the upper fragments of the two bones remain fixed in supination, hence the movement of pronation has taken place at the site of fracture and not at the elbow joint. If, then, this is not attended to, union of the bones will take place in such a position, and the mechanical result will be diminution or suppression of the range of supination according as the lower fragments have been kept in a position of partial or full pronation compared to the full supination of the upper.

A similar result is liable to follow fractures of the radius alone, and in these conditions an accompanying non-union of the ulna would rather serve to lessen the functional disability. It would allow of freer movement of the lower end of the ulna, which could thus rotate, instead of the lower end of the radius.

whose semicircular range has been either diminished or altogether suppressed.

It must be understood that we are dealing here only with the results of this particular form of mal-union—with fixed pronation of the lower fragment—and not with the other varieties of mal-union of the bones of the forearm, angulation, shortening of the radius, the blocking up of the interosseous space by excessive callus, or the occurrence of synostosis ; the practical conclusion to be drawn is that fractures of the forearm should be treated by immobilisation in supination, and not, as has been so often advised, in pronation or even in semi-pronation. In the gunshot fractures of the present war with extensive wounds and infective complications this is not always possible, but it is the goal at which we should aim.

Practical Conclusions

I have written this chapter, despite the dryness of its geometrical examples, because it seems to me to convey a lesson of great practical importance.

In the first place, I have endeavoured to show in the course of this chapter what care and attention we should devote to the correction of the displacements, active and passive, of the lower fragments of fractures ; pronation of the hand and wrist ; outward rotation of the leg ; backward displacement of the lower extremities of the humerus and tibia ; angulation in fractures of the femur.

And when we meet with a case in which such a mal-union has taken place, it is important that we should recognise its mechanical significance and not go on treating the limb by perfectly useless manipula-

tion or mechanotherapy. Massage, mobilisation, heat, baths, electricity—all constitute the veriest waste of time both for the surgeon and, what is worse, for the patient. There is nothing wrong with the joint itself, and the muscles are impotent to overcome the disability.

Yet I have seen many such cases treated for long periods by these means, which are from the very nature of the lesion useless, and all for the lack of careful clinical examination and accurate interpretation of an X-ray plate.

According to the importance of the functional disability in these cases, either leave them alone or perform osteotomy : the only treatment of the least use is to correct the axis of the bony lever. As to the exact nature of the deformity and of the correction required, their recognition will depend, in each particular case, on a knowledge of the phenomena we have described in this chapter.

3. The Excessive Formation of Callus

An excessive amount of callus is due to two causes : (1) imperfect reduction with overlapping of fragments. (2) excessive sub-periosteal osteogenesis.

This second cause has a maximum effect when the periosteum is infected, or at least abnormally irritated, even if infection itself is not apparent — which does not mean, however, that it may not really be present.

We see examples of this phenomenon, whatever some may say about it, in a number of simple fractures treated by open operation, with sutures, clamps and plates of various shapes and sorts. When

some time after the operation, successive X-ray plates of such cases are carefully examined, it is evident that the volume of sub-periosteal callus is abnormally great, and that it often keeps growing, little by little, for several months. This callus again remains tender to pressure, and even really painful; it has a tendency to undergo rarefaction around the foreign body that is keeping up the irritation, and secondary elimination after late suppuration is not uncommon, whilst surgical removal undertaken to relieve pain and persistent inflammation is at times necessary.

If this is the case with foreign bodies of surgical origin, whose asepsis is not always absolutely beyond suspicion, although at first apparently sufficient, it will be readily understood that when, in war surgery, foreign bodies remain embedded in bone the effect is bad even if primary suppuration has been absent, or only slight and of short duration.

This is frequently the case in certain fractures in which the covering of the bullet has been torn, and in which the lead has broken up into small pieces on striking the bone. (See fig. 6. The large foreign body is the hard covering of a bullet.) In such cases the callus produced remains for a long time hot and painful, and is only slowly absorbed and remodelled, specially if irritated by massage or untimely mobilisation.

The same thing happens, with more certainty, in the case of foreign bodies which are clearly infected, and it is on this account that, in my opinion, the various osteosynthetic operations are but rarely indicated in the immediate treatment of gunshot fractures. For the most part these pieces of metal are badly tolerated, they keep sinuses open, cause

necrosis, and—more often than is usually thought—result in non-union. I shall have to return to this subject later.

In general, excessive formation of callus occurs in infected fractures, especially in those in which sinuses remain open.

Even in cases which are not or are no longer fistulous, excessive callus is often the result of an infection, which is latent for the time being, but susceptible for an indefinite period of giving rise to a more or less acute exacerbation of inflammation—either spontaneously, or as the result of interference.

For the moment excessive callus concerns us inasmuch as it interferes with the function of neighbouring structures, which are displaced, compressed, or involved by it.

In the neighbourhood of a joint it limits the normal range of movement : we will discuss this in connection with ankylosis of joints.

Muscles, tendons, and vessels nearly always accommodate themselves fairly quickly and well to changes of relation and direction in this way imposed upon them. To liberate by operation adherent tendons seems to me to be but rarely indicated. On the other hand, the involvement of nerves which are enclosed, irritated, or stretched by callus is fairly frequent, and forms a clear indication for operation.

Excess of callus in such cases is usually but not invariably present; it does not, moreover, change the surgical indications at all, and only affects the technique of the operation to a slight extent. This consists in finding the nerve as near as possible to its point of entrance into the callus, but where it will certainly be free from it; with chisel and mallet the

nerve is then followed through the bone, in which a groove is cut along its course.

To understand properly the connection of certain nerves and certain bones is merely a matter of anatomy —*e.g.* the circumflex nerve winding round the neck of the humerus (its involvement is rare), the external popliteal around the neck of the fibula (involvement infrequent), the musculo-spiral around the middle of the humerus (involvement frequent).

The incision by which the bone is approached—most often the humerus in cases of musculo-spiral involvement—is the same as that for suture of the nerve or for freeing it from scar tissue. The only difference in the operation is that in the present case an uninterrupted nerve trunk is found which requires no suturing, but which does require to be protected, just as if it had been sutured, against any renewal of compression or involvement, the best method being, in my opinion, to encircle it with a flap of muscle taken from the triceps in order to remove all direct contact between nerve and bone.

The practical differentiation of the two conditions, solution of continuity requiring suture and compression requiring liberation, is, however, a matter of the greatest importance for the surgeon.

If division of the nerve is diagnosed, suture has a chance of success only when healing by first intention (I mean of the operation wound, and not of the nerve itself) is assured. The operation will therefore only be carried out when the fracture is united, and when suppuration has ceased for several weeks ; of course the operation must not be too long delayed, but, in order to ensure success, early operation is to be considered a matter of the second and not of the

first order of importance. Whether the division of the nerve has lasted a second or a year, the processes of degeneration in the lower portion and subsequent regeneration from the upper remain the same. There are of course many obvious reasons for operation without unnecessary delay so as to avoid as far as possible certain secondary lesions in the muscles and joints, but the chief concern is that the sutured nerve does not suppurate. I do not insist further on this point, which will be treated in a special volume.

If, on the other hand, compression or irritation of the nerve is diagnosed, it is necessary to operate at once, for ascending neuritis commences and increases quickly, and the nerve fibres must not be allowed time to undergo further degeneration. Operation should be immediate even if the fracture is still septic, and even if it is not certain that definite sequestra have as yet been formed.

When removing sequestra or operating on a bony cavity, if a divided nerve is found, the correct course is certainly to suture it, for very often it can be isolated sufficiently from the seat of suppuration; but this will be only an accessory to the main operation, that is to say, an exploration of the nerve would not have been undertaken if it had not been necessary to operate upon the fracture. This applies also to early operations on suppurating compound fractures.

The diagnosis between anatomical division and compression by callus is in theory very easy. The paralysis is immediate, sudden, and complete in the former case; late, progressive, accompanied by neuralgic pains, often with retention, at least partial, of some forms of sensibility, in the latter.

In the case of a patient who soon after being

wounded has come under the care of an observant surgeon in a hospital where there has been sufficient time and opportunity for a complete and thorough examination, this differentiation becomes subsequently a simple matter. But often at the base we receive wounded after several weeks or months, bearing labels on which the information is insufficient. This is inevitable on the evacuation labels from the field-dressing stations. In action there is no time to devote to detailed observations (which are, moreover, of little use), much less to write them on the label. It could, I believe, be avoided in the notes of a regular hospital. But I have had to regret, even from these, the frequent absence of any accurate notes. We are, then, often reduced to accepting the word of the patient, who has not always had the presence of mind to notice whether, at the time of the accident, a drop wrist or foot complicated the general uselessness of the limb, and once splints have been applied, has been no longer in a position to take notice of these points.

From time to time one is forced to remove a projection of bone that is threatening to ulcerate or has actually ulcerated through the skin.

4. False Joints. Loss of Bony Substance

(1) Varieties of False Joints

Before studying the treatment of false joints, it is necessary to distinguish with care the varieties of delay in union.

The average time necessary for the consolidation of a simple fracture in good position in a young and healthy adult varies, according to the size of the bone,

from one month in the case of a bone of the forearm to two months in the case of the femur. This period is lengthened (1) when reduction has been imperfect and the periosteum almost alone contributes to the formation of the permanent callus, (2) when the fracture is comminuted. It is an especially long period in cases of compound suppurating comminuted fractures, and in war surgery we have often to count on a fracture of the femur with or without a sinus taking from four to five months to become firm. A period longer than this constitutes a definite delay in union.

In theory, the difference between delay in union and a false joint is clear. Whatever time has elapsed, delay in union is characterised by persistence of the osteogenetic process ; a false joint by the final arrest of this process between the two fragments, each of which has undergone separate cicatrisation. In practice, the diagnosis between the two conditions is not always easy. The time that has elapsed, as I have just said, is not the criterion ; a simple fracture with an interposition of muscle becomes, so to speak, immediately an example of a false joint. On the other hand, certain fractures ultimately unite without any special surgical treatment at the end of a year or an even longer period. This remark applies especially to cases where irritation of the seat of fracture is kept up, suppuration having ceased, by the existence of a foreign body in the bone, whether it be a projectile, wire, a metal suture peg, or plate of surgical origin. One must judge of the question by radiography.

When the fractured bone remains flexible, if there is still a persistent sinus we should always admit in principle that it is a case of delayed union, and, after radiographic verification, extract the sequestra and

excavate the diseased area. Very numerous are the cases in which, after several months of suppuration, clearing out the infected area of the bone, specially if there have been sequestra, leads to a rapid return of the process of ossification, which previously had come to an almost complete standstill. In operating for chronic osteomyelitis I have several times noticed that in the middle of the sub-periosteal hyperostosis the fragments of the diaphysis were united only by dense fibrous tissue, which later has undergone ossification.

Palpation of the site of fracture supplemented by radiographic examination enables us to form a fairly correct clinical conclusion.

The principal characteristics of a real false joint are considerable abnormal flexibility, absence of pain on movement and pressure, and absence of tension and œdema in the soft parts that are more or less adherent to the seat of fracture. If the bone ends are still enlarged and the soft parts infiltrated with œdema, if the bones are only a short distance apart and the amount of abnormal mobility slight, if movement causes pain and even light pressure is painful, then one may safely conclude that there is merely delay in union, in which there is no indication for a hasty operation.

In these cases radiography gives useful information, but one must be able to appreciate the exact significance of the various details. In the first place, it should be remembered that callus, especially intermediate callus, often casts no shadow on an X-ray plate for a considerable time, even though clinically the union of the bone seems complete (see fig. 1); again, it is often impossible to diagnose by examination

of the negative cases in which the callus is still but poorly ossified; and when on manual examination we no longer find abnormal flexibility or tenderness, that does not mean that in the lower limb we may not be surprised by late angulation from bending of the callus under the body weight. The common fracture of Dupuytren long ago taught us the necessity of forbidding early weight-bearing when we suspect but slow ossification of callus.

When all suppuration has ceased and abnormal mobility still remains, radiography permits us to establish one of two points: the presence of a considerable bony loss, the end of the fragments being far apart, or else the presence around the seat of fracture of a greyish shadow with indefinite edges, a sign of very slow calcification of callus. In this latter case the value of successive radiographs at monthly intervals in order to follow by the increasing opacity of the shadow the progress of ossification will at once be obvious; even where there is considerable loss of substance of the shaft, regeneration of bone from the sheath of surrounding periosteum is not at all exceptional if one only has the patience to wait for it.

In the typical plate of a true false joint the shadow of the fragments should appear opaque and of a regular or irregular shape, but with very clearly marked definite margins like that of the bone of a completely healed amputation stump.

In war surgery the usual cause of a false joint in the shaft of a bone is this loss of too great an extent of bony substance, the result depending on whether there exists but one bone in the limb segment (arm and thigh) or two bones (forearm and leg). In the

former case, elevation of the lower fragment often allows consolidation to take place at the expense of considerable shortening. In my experience, pseudo-arthrosis in the shaft of the femur is rare; in the humerus, it is rather more common.

Where there are two companion bones in the limb segment, if one has escaped fracture, or if fractured has united without or with but little shortening, it places a very definite obstacle in the way of approximation and union of the two fractured ends of the second bone. This condition of affairs occurs sometimes in the leg, more often in the forearm. Pseudo-arthrosis occurring simultaneously in both of the bones of these segments is very rare.

A special form, "articular" false joint, occurs when the loss of substance involves an epiphysis in the neighbourhood of a joint as well as the neighbouring part of the shaft, and when the wound has healed without ankylosis of the joint, which becomes flail.

Occasionally this occurs at the knee joint after an extremely extensive resection for very severe bone involvement or when a partial instead of a complete resection has been performed. This form of false joint, moreover, sometimes follows a resection of the hip, which has succeeded in saving the life of the wounded man, but which has resulted in a limb of but moderate utility, although infinitely superior to an artificial limb fitted to the pelvis after a disarticulation at the hip joint.

The usual position, however, for an articular false joint is in the upper limb, sometimes at the wrist joint from loss of the lower end of the radius, more often at the elbow and shoulder from loss of the corresponding epiphyses of the humerus.

The regular pathological type of false joint is that of fibrous union, the tapering bone ends being joined together by bands of fibrous tissue; either close fibrous union, rather rare, when the bone surfaces remain in contact, and when, if there is no interposed muscle, a late, slow ossification may for a long time be hoped for; or flail fibrous union, more common, when a considerable length of fibrous tissue replaces the lost bone. I have not seen cases of real "false joint," that exceptional form with fibrous ligaments and synovial lining.

(2) Treatment of Non-union

It is necessary carefully to distinguish between the treatment of mere delayed union and that of true pseudo-arthrosis.

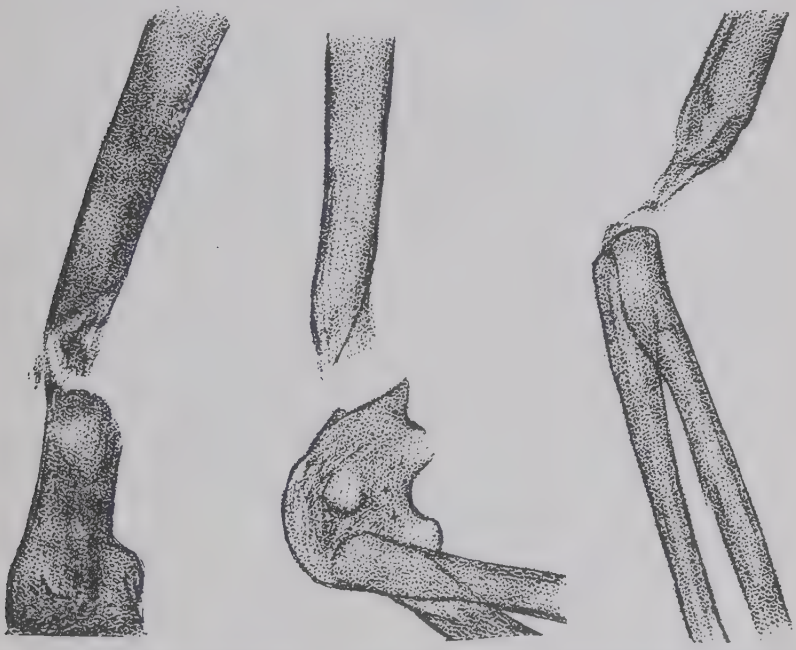
A. *Delayed Union*

I have already explained the rôle played in this by sequestra and foreign bodies, and the necessity for their removal.

In cases where neither of these two causes of delayed union exists, where suppuration has ceased, and there is no foreign body, and where on the removal of splints after the usual period abnormal mobility is found to exist, the difficult problem arises whether to persist in immobilisation or to leave the limb more or less unrestricted in its movements.

There are of course cases of delayed union—often wrongly described as false joints—in which, after a delay of some months, new bone formation has been stimulated by some purposive form of irritation of the seat of fracture—*e.g.* the old methods of treatment, forcible rubbing together of the fractured end, injection of mild chemical irritants, and acupuncture.

These various procedures are probably no more efficacious than permitting slight movement at the seat of fracture, the limb being either left free of all apparatus and lightly massaged, or else put up so that the movements of the neighbouring joints which



FIGS. 20–22.—Three examples of pseudo-arthrosis of the humerus; occurring in the middle of the shaft (fig. 20), in the lower part of the shaft with ankylosis of the elbow joint (fig. 21), the articular variety (fig. 22). In the last probably also the olecranon of the ulna has been resected. All three resulted in flail limbs, and in all were present sinuses which soon healed after the removal of small sequestra (fig. 20), or after excavation of a focus of caries (fig. 22).

are left unrestrained by apparatus cause a certain restricted amount of movement at the seat of fracture itself. A little movement is allowed, but only a little.

As a general rule, this latter procedure seems to

be preferable either to absolute immobilisation or to leaving the limb quite free. We should try it for successive periods of three to four weeks, noting at each change of apparatus whether the mobility appears less, and whether radiographs show an increase of ossification in the callus.

For this purpose the extension apparatus of Delbet for the humerus and femur, and his plaster splints, which allow the patient full use of the limb in fractures of the tibia and fibula, are most excellent. I am accustomed to apply these as soon as the pathological state of the parts allows of it, and to continue them as long as one is certain that a false joint does not exist.

If the delay in union is prolonged, particularly in the lower limb, and above all in the leg, it is easy to substitute for these heavy splints orthopædic apparatus similar to that prescribed for inoperable false joints, or for those in which operation has failed. This method of treatment avoids two very common practices which are to be condemned, viz. in the case of the upper limb, keeping the arm in a sling; in the case of the lower, giving the patient a pair of crutches.

Patient and careful observation is necessary before finally concluding that the process of consolidation has definitely come to an end.

B. *False Joints*

The means of treatment at our disposal are :

1. An open operation with the object of obtaining bony union.

2. The wearing of an orthopædic apparatus.

The principles of the orthopædic apparatus vary with the different segments of the two limbs; those of surgical operations are, however, general and constant.

(*a*) *If the fragments are in contact without loss of substance*, the old method of freshening the bone ends should first be tried. The seat of fracture is opened up, the periosteum preserved with the greatest care, intermediate fibrous tissue excised, and the ends of the bone freshened either with the curette or the saw, with the object of obtaining close contact between healthy, well-vascularised bony surfaces. By doing this there necessarily results a certain amount of shortening, usually of no importance in the case of the humerus, and even of the femur—where, however, pseudo-arthrosis rarely occurs—but incompatible with accurate coaptation of the cut surfaces in those segments of the limbs where there are two bones and the other is sound. If the separation of the surfaces is not great, this difficulty may be overcome by resecting a short segment of the normal bone; if the separation is considerable, we must have recourse to a bone graft.

After freshening the ends most surgeons assure the maintenance of the freshened surface in good and close apposition either by suture of the bones or by one of the methods by which this has been replaced and simplified in recent years (metal plates or staples), or else by an intramedullary peg of ivory.

I believe that there is a tendency to abuse the insertion of these foreign bodies in bone. Even when the seat of the fracture has throughout been closed and aseptic they irritate the bone, cause rarefaction, and provoke the formation of callus,

which is exuberant but at the same time insecure. Secondary sinuses are far from being exceptional. Moreover, it is often possible without these to maintain good position by means of well-fitting external splints; but when this latter course is impossible, it is, in my opinion, better deliberately to remove the foreign body as soon as the callus has commenced ossification. Consequently I prefer fixation with wire, or, better still, with a staple, to the use of intramedullary pegs.

(*b*) *If there is such loss of bone* (either originally or as a result of removal by operation) as is incompatible with coaptation of the fragments, we must have recourse to bone grafting.

Sometimes it is possible to insert into the gap a bony fragment with an adherent pedicle taken either from the bone itself or from a neighbouring bone. I shall describe this in connection with losses of substance of the tibia repaired from the fibula (see p. 452).

Most often a separate fragment is taken from a distance:

Either from the patient himself, *autoplastic graft*;

From an animal of the same species, *homoplastic graft*;

From an animal of a different species, *heteroplastic graft.*

It is generally recognised that success is more likely if the graft retains its own periosteal layer, but this is not indispensable.

In the case of a pseudo-arthrosis a graft of large size must be used, and most often an attempt is made to introduce its two ends into the medullary cavity of the existing fragments.

From the study of experimental grafts in animals,

and from their use in man in an aseptic field of operation, it has been found necessary to discriminate between two things, the "taking" of the graft and its ultimate fate.

I shall not consider cases where suppuration occurs and the graft comes away; the first condition of success is primary union of the operation wound. Further, it must be understood that antiseptics must not be used; they adversely affect the vitality of the cells.

In an aseptic case the graft usually "takes," even when it has been heteroplastic. In man, radiography has shown the bony fragment surrounded by callus; in animals, its survival and vascularisation have been established by post-mortem examination. The frequency of this immediate success should not, however, be exaggerated. More often than could be wished it is only partial: the fragment survives, but remains free at one end, sometimes even at both ends, and consequently consolidation is not obtained.

Even in cases that for weeks keep up a promise of ultimate success, one is liable finally to fail owing to a late but progressive absorption of the graft.

The present consensus of opinion is that even with an autoplastic graft this absorption is constant, or almost constant. The graft plays its part merely by exciting and directing an osteogenesis by substitution. This is a source of discussion of great scientific interest, but of no very great practical importance. If secondary ossification of the graft has occurred, it matters little whether the ultimate callus is formed by the transplanted bone itself or by new bone which has gradually replaced it, so long as in the end the continuity of the bony lever is re-established.

But if absorption takes place quickly substitution has not time to occur, and the final result is failure. Occurring in all three varieties of grafts, this excessively rapid absorption occurs in an increasing order of frequency with autoplastic, homoplastic, and heteroplastic grafts. Further, it may be said that the heteroplastic graft, the taking of which is more dependent on chance, and the absorption of which is more frequent, has not up to the present progressed beyond the experimental stage, despite a few fortunate successes, of which there are even some in classical surgery. This is a pity, because they constitute the most convenient method of obtaining at any time a massive graft.

An opportunity for the use of homoplastic grafts but rarely presents itself, and even when it does there is always the fear, despite all clinical and laboratory precautions, of inoculating the recipient of the graft with tuberculosis or syphilis.

Grafting by the autoplastic method alone is therefore carried out with any frequence, and the transplanted pieces are almost always taken either from the fibula (the whole middle third of the shaft of which can be resected without leaving functional disability), or from the tibia, whence a sufficiently long piece can be taken without difficulty from the crest.

Indications.—What I have said as to the absolute necessity for primary union after bone grafting, and its almost equal necessity after simple freshening operations with or without bone fixation, indicates that in war surgery the frequent recrudescence after open operations of infection, over which we have no control, forms a great stumbling-block in the way of success. It is advisable, therefore, to wait a very

considerable time before operating; all vascularity should have disappeared from the scar, and the neighbouring tissues should be quite supple, and even then there is no absolute assurance of success.

FIG. 23.

FIG. 24.

Even if the wound does not suppurate, failure to secure union is not at all rare.

In spite, then, of the incontestable progress of the last thirty years, the treatment of "false joints" by open operation remains uncertain. This is, however, no reason for refusing to consider operation as formally indicated if the functional disability is

serious—as is usually the case—even if in case of failure one has to fall back on an orthopædic apparatus: nothing is risked, and the gain may be considerable.

FIG. 25.

FIGS. 23–25.—Flail pseudo-arthroses of the humerus, involving the shaft (fig. 23) and the upper articular extremity (figs. 24 and 25). In cases 23 and 24 there are present sequestra whose removal was followed by rapid healing. In case 25 a sinus was due to disease in the fractured scapula.

I will now enumerate bone by bone the chief functional troubles which constitute indications for treatment.

In the case of the humerus, whether it be in the shaft itself, at the shoulder, or at the elbow, the type is that of a loose pseudo-arthrosis. This does not

mean that the limb is useless. In extension the arm hangs beside the body limp and swinging like a pendulum. But if the muscles are good—particularly the deltoid for the shoulder and the long muscles for the arm and elbow—the effect of their contraction is to raise the lower fragment, and then by supporting it against the upper, with, sometimes, a remarkable security, to allow of fairly vigorous action of the wrist and hand, the elbow remaining flexed. In the case of a false joint in the shaft the lower fragment is held by the triceps so as to make with the upper fragment an obtuse angle open backwards; in this position the biceps can quite adequately flex the elbow and hold it flexed. By the use of a circular armlet which leaves the elbow free, the functional utility of such a limb can be considerably increased. In order not to constrict the limb and interfere with muscular action it is best for this armlet to have a proximal attachment to a shoulder piece which is fastened round the trunk.

In pseudo-arthrosis of the humerus cure by open operation is most difficult to effect. When the head of the humerus has been resected with the upper part of the shaft a vigorous deltoid can raise the lower fragment directly and keep it in contact with the glenoid cavity. But in all the cases of this sort that I have seen in war surgery there has been complete atrophy of the deltoid, and if ankylosis had been effected the functional result would have been better. Hence in cases of this sort original resection of the upper end of the humerus should be performed only when, in order to save life, the choice lies between this resection and disarticulation at the shoulder joint. Conservative measures which would result in

ankylosis should be abandoned only after a full realisation of these facts of the case.

In the case of the elbow adequate voluntary movement at the site of the false joint is not rare; indeed some surgeons consider the functional result better

FIGS. 26 and 27.—Pseudo-arthrosis in the lower half of the radius (fig. 26) and of the ulna (fig. 27), in the latter bone with but little loss of substance.

than that of ankylosis of the elbow in good position—the muscles of the forearm and hand being equally good—therefore they prefer to treat by free and early resection fractures of the lower end of the humerus, of the upper ends of the forearm bones, or of the ends of all three bones. I speak here of immediate or early secondary and not of late orthopædic resection, which, being sub-periosteal, allows of the reconstitution and

remodelling of a firmly ankylosed joint. When the fixation by the long muscles is insufficient—when the muscles are poor, or else the loss of bone too great—the elbow should be fixed in an apparatus fitted with a ratchet, which encircles the arm and forearm, and is suspended from the shoulder in the manner already described to avoid compression of the muscles.

In connection with these fractured shoulders and elbows I draw attention to the attempts that have been made to insert under the soft parts artificial joints of ivory fixed to the neighbouring bones. I mention these solely to show that I am not ignorant of them.

Pseudo-arthrosis, even if fairly firm, of the two bones of the forearm results in a grave disability, which is sometimes complete. That of the radius alone is almost as disabling because of the loss or limitation of the movements of pronation and supination, and because of weakness of the fingers, the hand being flexed in a bad position; when the lower radial epiphysis has disappeared the hand deviates to the outer side, supination is impossible, and weakness of grip of the fingers is very marked. Pseudo-arthrosis of the ulna is much less disabling, especially when it occurs in the lower half. It may even be a good thing, especially when the radius is badly united, the lower fragments being pronated, causing sometimes less complete limitation of supination.

The forearm is the region where fibrosis and destruction of muscles and tendons and nerve lesions most frequently complicate non-union of bone and increase considerably the functional disability of hand and fingers.

If an operation by freshening the ends with shorten-

ing of the second bone (if it be intact) or by bone grafting fails, a fair result is obtained by the use of a

FIG. 28.—Pseudo-arthrosis in the middle of the shaft of the radius, with considerable loss of substance. Cavity containing sequestra in the ulna.

FIG. 29.—Loss of substance of the fibula without the occurrence of displacement of the foot (the external malleolus has escaped; ankylosis of the ankle joint).

leather armlet in pseudo-arthrosis of the shaft. Neither operation nor orthopædic apparatus is, however, of much use in loss of the lower extremity of the radius.

In the *femur* I have as yet seen no case of non-union of the shaft among the many wounded that I have examined. I believe that simple freshening without grafting would be sufficient. In case of failure, one would apply an apparatus transmitting the weight from the tuber ischii to the foot, like the caliper used in the convalescent stage of hip disease. The same also is useful in the case of a flail hip joint after resection; after this operation, however, ankylosis is much more commonly met with.

A flail knee joint, as I have already said, is rare; a permanent support becomes necessary for it.

In the leg, pseudo-arthrosis without being frequent is not rare. The most striking characteristic is the lack of stability in the limb in the standing position, hence there is a very considerable difference between pseudo-arthrosis of the tibia and of the fibula. A loss of substance of the fibula—even when considerable—is almost always without functional importance, provided that the external malleolus and its attachments are preserved; but if this is lost, deviation of the foot into valgus as soon as it touches the ground constitutes a very serious disability. The operative indication is then to arthrodese the ankle joint at a right angle, as is done for congenital absence of the fibula. I have seen a case of considerable loss of substance, but with preservation of the malleolus and stiffness of the ankle joint—which had been kept in a good position by the surgeon—walk very well and firmly, the sole of the foot flat on the ground (fig. 29).

Pseudo-arthrosis of the tibia without loss of substance, or with but slight loss—2–3 cm.—may often be treated successfully by freshening combined with shortening of the fibula, or else by a bone grafting,

by freshening of the two bones if the fibula also has not united. In cases of failure a walking apparatus, with support from the tuberosities of the tibia attached to the thigh, like but very much lighter than an apparatus for amputation of the leg, almost always gives a fair amount of functional use.

The most difficult cases are those in which there is such excessive loss of substance of the tibia as renders impossible any attempt to procure contact between the two ends even after resection of the fibula. By means of a bone graft it is also impossible to reconstruct the tibia sufficiently in length and in thickness. In such conditions, sometimes callus forms spontaneously in a favourable manner, one or both ends of the tibia becoming united to the fibula, which has itself been broken but has joined, so that the fibula itself transmits the body weight; this bone is reinforced by callus—it seems to develop later little by little, and adapt itself to its new function, and the final result is often satisfactory. It is possible in some cases to imitate this natural process by surgical methods (figs. 30 to 33). Sometimes the shaft of the fibula has been implanted into the upper end of the tibia; sometimes, on the contrary, into the lower end of the tibia; sometimes, by two operations, both ends of the fibula have been implanted in turn, so as to substitute one entire shaft for the other (figs. 35 and 36). In this last case, although the absence of the middle part of the shaft of the fibula usually results in no disability, it is well to guard against the occurrence of a valgus deformity of the foot by creating a synostosis between the lower ends of the tibia and fibula.

It is more in accordance with the normal mechanics

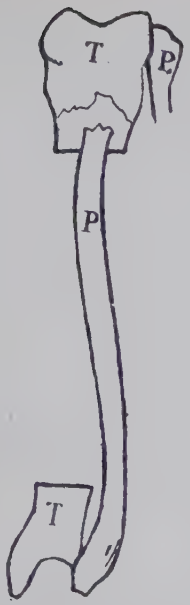


FIG. 30.—Simple transplantation of the upper end of the fibula into the upper fragment of the tibia.

FIG. 31.—At the time of the operation.

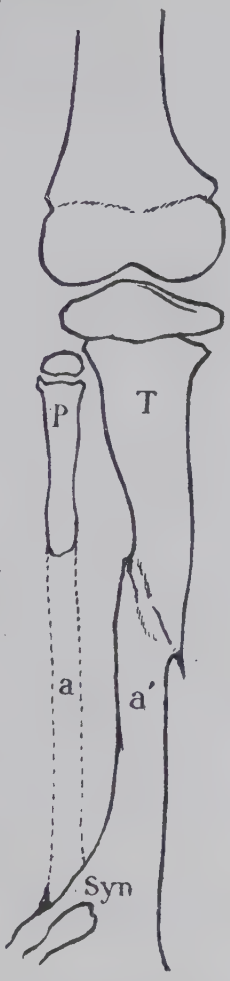


FIG. 32.—The final result.

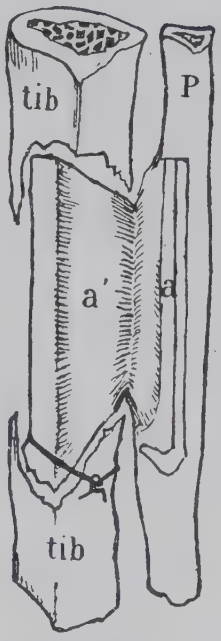


FIG. 33.—The operation of Curtillet—a fibular flap *a* is transplanted into *a'*, the gap in the tibia due to loss of bone.

FIGS. 31 and 32.—After grafting of the upper end of the fibula into the upper end of the tibia, and after the performance of arthrodesis of the inferior tibio-fibula articulation, the fibular shaft *a* replaces the tibial shaft *a'*.

of the leg, however, if, following Curtillet, the transplant is taken not from the whole of the fibula but only from the anterior half of its thickness. This osteoplastic strip, nourished by an internal pedicle formed of musculo-periosteal insertions carefully left untouched, is passed through an opening made into the antero-external muscles of the leg, and is placed between the two ends of the tibia, freshened and shaped like a fork (fig. 33).

After these various operations it has been frequently proved that the graft, studied by a series of radiographic plates, has rapidly grown and become an excellent tibial shaft.

Thanks to these methods, operative and instrumental, we may say that amputation is no longer indicated at the present time so far as the upper limb is concerned, and hardly ever in the case of the lower limb. It is possible, however, that in certain cases of flail pseudo-arthrosis of the leg this mutilation may be advisable—as in certain congenital false joints—if we consider that the apparatus will be more simple, and the support more secure with one of the excellent artificial limbs that can be made to-day for amputations in the lower part of the leg.

C. Cases of Non-union with an Unhealed Wound

Under these circumstances it is impossible in any individual case to be certain that union will not eventually take place; I have already pointed out how quite often after a clearing out of sequestra and patches of diseased bone further osteogenesis results in the attainment of late union. Where the destruc-

tion of bone has been extensive, however, the case will most probably end in the occurrence of a pseudo-arthrosis. In such cases very interesting results have been obtained by an extensive freshening followed by plating of the fragments, and this in the presence of sepsis; the wound is left open and the plate removed some few weeks later. The irritation induced by the septic plate seems, at any rate at first, to be favourable to the sub-periosteal production of new bone. In many cases this procedure will mean a considerable shortening of the bone, so that it is really applicable only in threatening pseudo-arthrosis of the femur and of the humerus. As regards the femur—non-union of which is, moreover, very rare—I have seen no published record of its adoption; in the case of the humerus, however, Tixier obtained a good proportion of successful results, of which he gave an account some months ago at the Société de Chirurgie. I have had occasion to remove both from the humerus and from the bones of the forearm plates of the Lane and the Lambotte patterns that were the cause of persistence of certain sinuses; these had, in my opinion, been left in far too long; nevertheless, I am certain that they played an essential part in the attainment of union in these cases.

SECTION III

MENTAL DISORDERS

MENTAL DISORDERS

PART I

CLINICAL

CHAPTER I

ACUTE MENTAL DISORDERS

ACUTE mental disorders are the most frequently met with, and are also those for which an exact diagnosis and a right solution are indispensable. It must, however, be remarked that acute does not always signify of short duration. In neuro-psychiatry one must expect to count by weeks, or even by months.

For greater clearness, I have classified these diseases into several groups, somewhat arbitrarily, as there is generally some blending of the symptoms of one with those of another. The four principal groups are as follow—

Mental Confusions, in which condition there is a perceptible clouding of the mental faculties.

States of Depression, in which the intellect is less implicated than the emotions, and in which there is great distress.

Neurasthenic Conditions, which partake of both the preceding groups, are less serious, but sometimes more lasting.

The Conditions caused by shell shock and their results, a separate group, characterized by their special

etiology, by their frequency, and the seriousness of their consequences.

Then there are symptomatic groupings of less importance, and answering to cerebral excitement, to mania, to encephalitis, and to acute meningo-encephalitis. Except the last group, the constitution of which we shall study further on, all these mental diseases have a common etiology, and most often a complex one. They owe their origin to fatigue, intoxication, or emotions, of which mention was made in the Introduction. All these maladies may affect persons hitherto mentally healthy. But also, all these cases, when closely observed, reveal certain accessory causes.

First—*Predisposition.* That emotional organization whose character Dupré has so accurately laid down shows itself very distinctly in some persons. In those cases—which, as we shall see, are rare—in which emotion is the sole originating cause of the malady, we may suppose that the patient was constitutionally feeble. And this weakness may manifest itself not only as regards courage, for there are slightly unbalanced persons, of weak mind, who do not lack energy or courage, but whose brain gives way because of their predisposition. Another important factor is that the army is a crowd, and that these acute psychoses may be regarded as mental contagions. Whatever may be the general predisposition affecting the men of a squad, whatever the circumstances may be, there are units which will not be mentally affected, while a neighbouring unit placed under the same conditions will pay a heavy tribute. This may be because the first unit has been free from the ferments of demoralization and indiscipline, so rightly dreaded by those in command of such unreliable subjects, not always faulty, sometimes really ill, of whom one only will contaminate a company. This depends much upon who is in command. At the beginning of the war, those who had some experience of pathological psychology, and who could realize what was the average of

the terrible alcoholic saturation of the nation, awaited the news of the first days after mobilization with heavy hearts. Even taking into account the splendid spirit of the mobilized men, what would this immense crowd —excited, eager, and athirst—turn out to be, when flung into the furnace? It is to the eternal honour of our staff of officers, active and in the reserve, that they should have been able, at the cost of unheard-of individual sacrifices, not only to keep the men up to their duty, but also to keep them calm. As time elapses we shall see the achievement of these admirable leaders, of whom so few still remain, even enhanced. The moral influence of the commander, his example, his anxious care of his troops, are therefore favourable factors of the first importance. On the other hand, in a unit deprived of its officers, or badly kept in hand, a real psychical epidemic may break out, either of hallucination, mental confusion, or depression, if any cases of the kind already existed in it.

I.—MENTAL CONFUSIONS

It is rarely that mental confusions develop suddenly, or, more accurately, apart from those cases in which some serious occurrence has caused a complete upset, the onset is sudden only in appearance. When the patient shows by his manner or his speech that some change has taken place in him, he simply reveals a state which has taken some time to develop. There is, therefore, to a degree varying according to the circumstances, a sort of prodromic period of mental confusion, which it is all the more necessary to discern since it is found, with some modifications, at the beginning of the states of depression.

This first phase corresponds fairly well with that which is classically described under the term of simple mental confusion, as distinguished from hallucinatory confusions, which will be dealt with later on.

§ 1. Simple Mental Confusion

The special characteristic of mental confusion is cerebral torpor. The patient sometimes sinks into it unconsciously, especially when the conditions of war impose on him a monotonous life, lacking any call upon personal initiative. Often, however, a subjective symptom precedes the stupor; this is cephalalgia. Régis, who has done so much to increase our knowledge of mental confusion, has brought to light the importance of this cephalalgia. It sometimes precedes by several days any other morbid manifestation; it is persistent, diffused, usually fronto-orbital or occipital. Often it has very painful exacerbations, especially in the morning after a bad night. It is never a distinctly localized neuralgia—it very rarely takes the form of hemicrania. Its connection with sleep should be insisted on. The entire history of mental confusion is bound up with that of sleep, the normal mode of repose for the brain. Confusion is essentially a psychosis of exhaustion.

Sometimes the headache is very slight, notably among labourers, whose cerebral sensibility is obtuse. But the patients then describe a feeling of emptiness, or, on the contrary, of fullness and heaviness, in the head, which has the same significance.

Sleep is disturbed in two combined ways: during the night it is less profound than usual, broken by nightmares, the repetitions and the intensity of which gradually conduct the patient towards hallucinatory mental confusion, to a dreamy state which will be referred to later on During the day, the ordinary state of wakefulness is less complete. There is less clear-headedness, brain activity, or power of attention. The sensation of sleepiness may be absent, but the man is asleep while awake, pays no attention to orders, is forgetful of instructions, incapable of reasoned reflection, slow to understand the simplest ideas, inert and stupid.

He is tired also, with an uncomfortable fatigue,

which can find no rest, and which the least effort or the least noise accentuates. He has sudden weaknesses, sensations as of passing faintness, for which he cannot account. He suffers from dizziness, giddiness, sometimes palpitation of the heart.

The appetite is distinctly less, the tongue foul and coated, the abdomen swells and the bowels become indolent. The man becomes rapidly thinner, and the emaciation corresponds with the sleeplessness. The expression becomes more and more dull, the movements uncertain, and sometimes, as the case progresses, inadequate to the feelings of the moment. When these phenomena are noticeable in a unit exposed to bombardment, or in charge of a trying sector, the fatigue due to the circumstances is a sufficient explanation of them. But they may appear apart from any special occasion, and as they are on the whole slight, they may be misunderstood and taken for unwillingness, or a purely moral failure of energy. Thus a certain number of confusional cases are at the outset defaulters, men who have been punished; and it is in prison that one is impressed with the permanent and progressive character of their physical and mental malady. It is unnecessary to add that the sojourn in disciplinary quarters, and the dread of the court-martial, aggravate their malady.

We see, therefore, that simple mental confusion, a combination of physical and psychical signs, approximates to the state of fatigue pushed to an extreme degree. The confusion is distinguished from mere fatigue by an element of toxic indigestion, more marked than in fatigue, and also by a sort of incapacity for rest of body and mind. In the elementary and transitory cases these are the only symptoms, but there are many intermediary stages between these elementary cases and the most serious ones.

These *intermediary* stages proceed in two directions, often combined: on the one hand towards hallucinations and raving, and on the other towards a more profound intellectual hebetude and amnesia.

§ 2. Hallucinatory Mental Confusion

Hallucinatory mental confusion has one essential element, namely delirium. By this one fact there is less risk of its being passed unnoticed, but those cases which are affected by it are not immune from diagnostic errors and mistaken treatment. The first mistake that may be made is to take them for alcoholics. When Lasègue wrote "the delirium of alcohol is not a delirium but a dream" his formula was such a happy and apposite one that it had a great success. But, as often happens, medical opinion has exaggerated its import. In spite of all the work of Séglas, of Régis, of Charlin, we are still too apt to believe that all illusions and hallucinations of sight are alcoholic.

Now, even though alcohol does unfortunately play the part already spoken of with regard to the mental disorders of the Army, it does not include them all, and notably many of the delirious visions supervening in the course of mental confusion have nothing to do with alcoholism.

In other cases, sufferers from confusional hallucination are mistaken for cases of persecution mania, and the surgeon, preoccupied above all with disposing of them and preventing them from doing harm, loses sight of the urgent necessity of treating them.

We know how the delirium of the dreamy state originates. It is merely the development of that state of half sleep and nightmare which is simple mental confusion. Little by little, in a few nights, the nightmares are prolonged into the morning, when the patient is still only half awake; they return during the day as soon as he shuts his eyes; then they persist even when his eyes are open. By that time there is established a state, the secondary character of which, and its analogies with somnambulism, Régis has so clearly pointed out. It has often been described in alcoholic cases, haunted especially by visions of animals.

In these cases, battle-scenes, in the shape of brief, manifold, incoherent impressions, are imagined by the

patient and lead to agitation, cries, onomatopœian words, boum-boum-boum, and the gestures of defence or of attack. Or possibly the hallucinatory scenes are better co-ordinated, and the patient is for the time playing a part. In rarer cases it is always the same vision which recurs, especially some scene of horror, which has had the effect of an emotional shock on that particular person, and stamped its imprint on all his ravings.

This prolonged dream, disquieting or dangerous in its manifestations, and often making a great impression on those around, even when the patient is harmless, is accompanied by the circulatory and digestive physical signs of mental confusion. But one result of the originating emotion is an over-excitement of the circulation; the pulse is full, though compressible, and the colour is higher than in the simple form. It is not uncommon to observe a profuse perspiration and a slight feverish tendency. The dreamy delirium may manifest itself suddenly: a man under arms is agitated, gesticulates and menaces, or perhaps, while in the trenches, begins to fire at random on the enemy. But, as I said before, this sudden development is only apparent, for the morbid process had begun some time before.

Usually the period of dreamy delirium does not last beyond three weeks, and many patients recover their senses more rapidly. But prompt treatment is an essential condition of this transience; and the illness is not over when the excitement disappears. Its somewhat dramatic aspect engrosses the attention, but along with the hallucination the patient still remains a case of confusion, the mind profoundly obscured in all its normal operations, incapable of retaining and fixing the memories of present occurrences (amnésie de fixation).

Without entering into an etiological discussion, which will find its place later on, one remark must be made here: in the early stages of the war, hallucinatory

mental confusion was more frequent than it is now. It naturally belongs more to the war of movement than to the war of positions. It is brought on by fatigue, and by those gastro-intestinal disorders which are more frequent and more severe when the commissariat is disorganized. Alcoholism was more rampant at the beginning of the war, and reinforced the condition; and finally, from the psychical point of view, it is possible that the average man is now better prepared for the sights of battle, and so is less impressed by them.

Judging from all the evidence, these cases of hallucinatory confusion are the most dangerous to have at the front. This is not only because their madness leads them to commit acts dangerous for those around them, or draws on them the attention of the enemy. Some confusional cases are quiet in manner, their hallucinations are slight, and the chief element of their madness is their intellectual bewilderment. It is they who leave the cantonment, straying haphazard, or when on patrol go wandering into the enemy's lines. On the other hand, there are others who, subject to terrifying and panphobic hallucinations without counteracting control, run away, also at haphazard. It is unnecessary to lay stress on the seriousness of the medico-legal problems raised by these cases.

§ 3. Acute Mania

All mental confusions depend on structural lesion of the brain. Even in the mildest cases the brain cells suffer from innutrition, so that from the physiological as well as from the psychological point of view mental confusion means mental insufficiency. The brain, like our other organs, is liable to acute insufficiency. There is an acute mental insufficiency, anatomically characterized by an intense inflammation, which is rapidly fatal. It is called acute delirious mania, a clinical appellation which dates from the time when we were still unaware of the cellular lesions accompanying it.

Acute mania, a much discussed subject, is observed as the final stage of certain serious infections (pneumonia, typhoid fever, eruptive fevers, microbial meningitis). But it has attributes of its own, constituting the maximum degree of mental confusion. It is necessary to become acquainted with it, if it is only to enable one to make a prompt prognosis, which should, however, always be a very cautious one.

It is a mental confusion with particularly accentuated symptoms, and which runs a very rapid course. The phase of simple confusion varies in duration, commonly it is only a few days. Then, suddenly, violent mania comes on. The patient is completely bewildered; there are incessant hallucinations, restless movements, trembling (the delirious tremor of the drunkard is an attenuated variety of this), the knee jerks are exaggerated, speech is impeded by the tremor, sometimes the pupils are unequal, or very dilated. Certain spasms constantly recur, particularly that of the pharynx, so that in rare cases there is pronounced hydrophobia.

The digestive functions are profoundly affected; the secretions, at first abundant, dry up; the perspiration becomes viscid, the urine scanty, the heart slackens and becomes irregular, and death occurs, sometimes thirty-six or forty-eight hours after the onset of the mania, sometimes not till later, towards the fourth or fifth day. After that time the chances of recovery improve, and the case approximates to one of ordinary severe mental confusion.

Usually, this acute delirious mania is accompanied by a very high temperature, at least 40° C. (104° F.), and sometimes even more than 41° C. (105·8° F.).

But the excitement may occur some time before the fever, from which arises a serious difficulty of diagnosis. If we take account only of the excitement, the case appears to be one of mania; if we dwell too exclusively on another symptom, we may regard it as one of excited general paralysis, and this is a mistake often made.

It is still more difficult to eliminate rabies. Indeed, the hydrophobia, and the constant expulsion of the saliva, which is only a consequence of the hydrophobia, incline one to suspect rabies; the more so as this also in its final manifestation is an acute mania. A non-rabid acute hydrophobic mania does exist, as numerous autopsies, followed by inoculation of a rabbit's nervous centres, have proved. But there is no decisive clinical indication to distinguish it from rabies, unless it be that in some cases the severity of the digestive phenomena may point to mental confusion.

Acute mania, contrarily to what was at one time believed, is not to any extent a psychosis of emotional origin. It is an encephalitis, infectious or toxic, aggravated or perhaps even caused by an insufficient destruction or elimination of toxins. Its prognosis, in any case, depends on the action of the emunctories. There is no hope if the kidneys cease to act. I have seen ten cases of this since the war began, all fatal. Only once did it occur in a proved drunkard, and it is probable that alcohol played no part in any of the others.

§ 4. Mental Confusion with Stupor (Narcolepsis)

The confused patient is bewildered, indifferent, and inattentive. A step further, and his condition is that of stupor. This form is not common in ordinary mental pathology, and, above all, is rarely acute, while it does, by itself alone, account for a good many of the indefinitely slow and prolonged cases which are intermediate between acute mental confusion and chronic mental confusion. In war pathology it has, on the contrary, a great importance. It makes a distinct part of the syndrome of shock, to which we shall return. It also constitutes, even when an explosion has not taken place in the immediate neighbourhood of the patient, a somewhat special syndrome

of slight shock. It is particularly noticeable after a prolonged bombardment, when a sort of adaptation to the concussion and noise takes place. The patient is less painfully impressed, but he falls into a kind of torpor, which corresponds to some extent with the first stage of simple mental confusion, but which, if the bombardment is prolonged ever so little, does not stop there.

" I cannot sleep, but I cannot keep myself awake," says André Gillas, in his excellent *Notes of Battle.* And further on : " My eyes close of themselves, in spite of every effort, and I dread this torpor, for madness at once seizes on me. If only I can hold out to the end ! "

Then, interspersed with visual hallucinations, of which the clearness and fullness depend greatly on the intellectual culture of the patient, a " mental " sleep, if one may so term it, overmasters the patient. It is not a true sleep, restful and recuperative. One cannot always rouse them from it, not even by shaking them. It is an annihilation of the worn-out consciousness, a "second state," a somnambulism. For a long time it permits of the continuance of all automatic acts, the sub-consciousness remaining awake and answering to certain stimuli. The reflexes remain normal, those of the vegetative life in particular; deglutition is perfectly performed when liquid is poured into the patient's mouth.

But the patient is inert and immobile. He even neglects the movements of elementary defence, such as driving away a fly that walks across his face; his cutaneous sensibility dies away, as does the diminishing instinct of self-preservation. He will not take shelter if the place in which he is becomes more exposed. He remains where he is, seated or lying down. The face is calm and remarkably expressionless, its animation is extinguished, as it were; the circulation is normal, with a low pressure; the respiration is not quickened.

This lasts during the time of bombardment, and

thereafter for several hours, or perhaps for several days. It is not uncommon for this condition to be transformed into a real sleep when once the patient is sent to the rear, as if in spite of all, the unconscious man then perceived that his being was in safety and could realize its desire to sleep on.

I have taken as example of this particular stupor that caused by bombardments, because its frequency increases in proportion to the prolongation of the war. To it we owe in part those prisoners whom we gather in the course of an attack that was well prepared by artillery. The men left in the front line under such conditions, cut off from the rear by an ample barrage, without food supply, are all more or less under the influence of this stupor. But some among them may, on the contrary, show signs of excitement under these circumstances. These are the patients in whom the hallucinatory element develops easily, and who display dreamy delirium. But these are exceptional.

Of what does this stupor consist? To begin with, some looked on it as hysterical, that is to say, that, to their idea, it was due to emotion. It has been described under the name of battle hypnosis (Milian) and of narcolepsis (Roussy). As a matter of fact, if a depressive emotion has some share in it, it is shock and fatigue of the nervous system that are the chief causes of it.

Previous sleeplessness has its influence, as also has the impossibility of getting any normal sleep during the whole time of the bombardment. But it must not be supposed that this confused stupor is a sleep. It is not in any sense a protection of the organism. It is a failure of protection. We have long known, and it has been proved of late years by most interesting experiments (Piéron), that sleeplessness creates toxins. Men placed in these special conditions in which sleeplessness is added to lack of food and drink, and the accessory influence of alcohol, taken as a temporary stimulant, but which in the long run has a toxic effect, are, above all things, poisoned men, in whom,

perhaps, the material shock has produced a special sensibility of the nervous system. On this account they certainly come into the class of the mentally confused. For the rest, one must bear in mind that acute mental confusion with stupor may be met with away from the firing line, as a simple auto-intoxication. Its prognosis then is less favourable than in those cases coming from the battle-field, and which a short rest ordinarily suffices to improve greatly. It is more slowly developed, often under cover of a depressed condition in which delusional ideas of a melancholic nature may occur. Pathogenetically it is a hybrid, and a subject to which we shall have to return.

There are also cases of confused stupor which come on suddenly, or rather in which the element of stupor manifests itself all of a sudden, in the course of a mental confusion which has passed unperceived till then. I have in my department a man who, being in the front line of a particularly hard sector, ran away, and for this was condemned to death by a court-martial. At the pronouncement of the sentence, he fell into a stupid attitude—a state of attonitus. Despite strong presumptions of malingering, he was brought before a board of medico-legal experts, which diagnosed the preliminary phase of dreamy delirium, during the course of which the flight had taken place, and proved the pathological nature of that action. The state of stupor little by little disappeared, but it took several months to disperse, and there remains a mental impairment which will probably persist.

§ 5. Amnesic Mental Confusion

There is always an amnesic element in mental confusion; perhaps it is still more marked in the psychosis of war than it is in the toxic and infectious confusions of peace-time. At all events it is sometimes of exceptional importance. There are cases of confusion in which nearly all the symptomatology is limited to defect of the memory; that is to say, of

the *apparent* symptomatology; for here, too, the malady is more deeply seated than it appears at first to be. But, at the front, in the conditions under which a diagnosis has to be made, appearances are not to be neglected. Here is a man who is certainly the exhausted patient referred to before when speaking of simple mental confusion, but who still appears to have some physical energy. What strikes one in him is that he forgets: orders, elementary precautions, events of the day, all are effaced from his memory. On questioning him, we discover that in reality the recollections have vanished because they were not fixed. It is in the highest degree an amnesia of *fixation*, an incapacity of seizing and retaining impressions.

Indeed, it is mainly a malady of attention and ideation. The man does not understand, and his attention is fleeting. When we have known the patient to be normal a short time before, the first thought that comes is that it is another case of simulation or malingering.

Not infrequently, fortunately, one circumstance decides the diagnosis, and at the same time the indications are more distinct. The attack of amnesia comes on after some particular striking event, or more often after some prolonged effort. It sets in at the trenches after an assault, or simply after returning from the trenches. We recognize then that failure of the over-strained nervous tension which is one of the principal conditions of these acute psychoses. The amnesia may show itself quite suddenly, and to a most improbable extent. There are men, officers, who can no longer remember their age, the number of their regiment, not even their name, or if they are married. This is a kind of total amnesia which is not altogether exceptional. It has been known for quite a long time, particularly in colonial pathology, and has been attributed to masked ague, or to sunstroke. It is very likely that these were the real causes since every element of cerebral congestion may aggravate and complicate the state of mental confusion.

Régis has rightly remarked that, when it is as complete as this, the amnesia has in reality an element of dreaminess. It is because their brains are haunted by delusive imaginings that these patients are so distracted about everything concerning their most natural remembrances.

Amnesia is also a mode of termination of mental confusion, as Séglas has shown in his still classic *Leçons*. Commonly the convalescent has only a vague remembrance of the onset of the delirium, or the period of stupor, or perhaps only the impression of a "hole." Also his memory of recent events returns slowly. It is another phenomenon of fatigue, of distraction.

Chavigny has designated by the term of "aprosexia" (inaptitude for attention) this amnesic mental confusion, of which he has given some very interesting examples. In one, the origin of which had been an emotional shock, and also a fall of three metres high, the clinical picture showed a mingling of amnesia and automatism bordering on stupor.

Moreover, one must expect that this confused amnesia will assume infinitely varied forms, circumstances and the temperament of the subject determining its varieties. There is a remarkable study of it in the second article by Georges Dumas on "Mental Diseases and War" in the *Revue de Paris* for July 15, 1916. Georges Dumas has remarked, and my own observations confirm his, that in these cases the patients retain their remembrance of those practical acquirements which have long become automatic. On the other hand, in those cases of amnesia in which the memory of the past is scarcely affected, it is just those special acquirements that one might well believe to be fixedly automatic that are lost.

Georges Dumas instances the case of a man who had forgotten Latin; I have several times seen polyglots who had forgotten a perfectly familiar language, but not that of their Mother Country. It is a peculiarity which we shall meet with again when speaking of cerebral traumatisms later on.

These amnesic confusions are not simply clinical curiosities; they sometimes raise medico-legal problems which it is necessary to know. To begin with that of running away, which may happen in a phase of amnesia by virtue of automatism, and is all the more serious for its perpetrator since the symptoms of mental confusion are at a minimum, and interrogation of the patient does not dispose one in his favour. As he recollects nothing, as he cannot give any valid reason for his flight, one can get nothing out of him; and from that to looking upon him as concealing something —"shamming Abraham"—is only one step. There are worse cases than the individual misadventures of an amnesic runaway, worse than the failure of a clouded memory. There are the false remembrances that mislead as to the true. In these particular cases this is called fabulation, or paramnesia. Men come and recount exploits at which they have assisted, and which inquiry shows to be imaginary; or they denounce, with an impressive profusion of detail, communications with the enemy of which they have found the evidence. The consequences are manifest. Assuredly if we closely examine these dangerous witnesses we may find in them signs of mental confusion, may perceive a certain incoherence in their story, contradictions and improbabilities. But it needs a very cautious spirit to be so much on one's guard.

These false witnesses are perfectly honest. At most, when they are proved neuropaths, one may ask oneself if their assertions are not exaggerated, if they are as sure as they say they are of the truth of their tales. This strange affliction, from which they themselves are the first sufferers, is well-known. Notably it has been described in connection with polyneuritic psychosis, which, as every one knows, depends on cerebral lesions, despite its name. It also occurs in presbyophrenia, which is a variety of senile dementia. This fabulation, or paramnesia, is caused by the uncertainty and the vagueness of real remembrances, and also by mistakes of the memory,

such as the illusion of "already seen," or "already experienced." Polyneuritic psychosis and presbyophrenia are partly toxic processes, and definitively varieties of mental confusion. Consequently it is not surprising that these psychological peculiarities should be found in the mental confusion of war, in which the seriousness of events, the rapidity of their succession, and sometimes the unexpectedness of their occurrence, are certainly of a nature to strike the imagination and falsify the memory.

§ 6. Clinical Summary

Mental confusion includes the mass of morbid phenomena connected with cortical insufficiency, both acute and temporary: an insufficiency that is confined to the most delicate part of the psychic functions. It allows the mechanism of what we call, in default of a better term, the sub-consciousness, to exist intact; it corresponds to the obnubilation of the centre O in the *schéma* of Grasset; the delusional manifestations interpret the activity of the sub-consciousness.

The military consequences of this cerebral disorder are all the more serious because certain forms of mental confusion may pass unperceived. It is, therefore, necessary to determine precisely the origin of the state of confusion, and the factors in the diagnosis.

However, it will often be possible to recognize the imperfect forms by examining carefully into disturbances of sleep, of memory, and the bewilderment of the patients. We should also note any signs of digestive or general toxic infection, the impairment of the circulatory and secretory activity, the frequent diminution of the quantity of urine, the disturbance of the temperature, which may be either raised or depressed; and sometimes there are other signs which indicate a cerebral attack, vaso-motor or sensorial disturbances, even slight convulsive fits, or partial and transitory paralysis.

§ 7. Etiology

The mental confusions of peace-time have an infectious or toxic origin. It is exceptional for an emotional element to take part in their production. It is not the same with the mental confusions of war. Emotion, especially depressing emotion, is a potent cause of nervous fatigue. It produces an actual cellular exhaustion, and by its own intensity often acts as the determining factor. Therefore, in a considerable number of cases, its influence must be added to that of toxæmia and infection.

There are also other mental confusions which have not yet been considered, viz. those of the wounded. The suffering and the hemorrhage, by themselves alone, and before the development of infection, are elements which we may almost be surprised to find are not more hurtful to the brain than they are. In fact, we shall meet with them again in connection with the states of depression. But we must note in passing that the old delirium of the wounded, evidently infectious, was nothing other than mental confusion.

If there are but few of the wounded who are also confusional cases, on the other hand, mental confusion forms part of the syndrome of shock. From whence then arise, in practice, apart from the wounded and the shell-shocked, these cases of confusion?

Infectious illnesses, even after recovery from the febrile period, notably typhoid and para-typhoid infections, pneumonia, influenza, and acute bronchitis, are all responsible for a certain number of cases. It is even possible, exceptionally, that anti-typhoid inoculation may have the same effect. Gastro-intestinal auto-infections, and often also the alimentary, have a much greater numerical importance, as has been particularly well demonstrated by Chavigny. To this must be added the heat, and above all, sunstroke, cases of which have been somewhat numerous in our Eastern army.

But the aggregate of all these favouring or deter-

mining conditions is not equal to the influence of alcohol. This, capable by itself of producing the most serious forms of mental confusion, at the very least weighs down the scale in a considerable number of cases.

Finally, there are states of confusion in which the infective and toxic influences are extremely restricted, and which depend solely, or nearly so, on *emotion acting on a predisposed nature*. From the clinical point of view some of them are of a trivial type, such as those patients in my department who were normal during the day, and whose morbid state only appeared at night in the form of hallucinatory attacks, which were simply attacks of somnambulism, caused by the war, and coloured by it.

Or, on the contrary, there may be excited cases of mental confusion, a great uproar, and corresponding to those which Séglas has described under the name of *hallucinatory delirium*, and Farnarier under that of *acute hallucinatory psychosis*. These are certainly cases of mental confusion, but of a more insane type. They show themselves sometimes under the form of a relapsing or periodical psychosis.

The following example may serve as a type—

R., age 29. Two brothers died of meningitis. Mother an unbalanced neuropath. Himself at the age of eighteen passed through the special Infirmary of the Dépôt, and made a short stay at Saint-Anne after a sudden attack of excitement. Suddenly, and for no reason, he took to publicly insulting an important political personage by shouts and speeches in the streets, and chalk inscriptions on the walls. At the front, for the first few weeks he had no sleep, after that he slept fairly well. One day, during a moderate bombardment, he was again seized with a fit of violent and incoherent excitement. It subsided in a few hours. Soon afterwards, a similar scene occurred, in the course of which he deserted from his company. Transferred to my department three days later, he was at first perfectly calm during the day, but had nightmares at night,

during which he fought mimic battles; or, on the contrary, merely spoke in a loud voice. Then the agitation increased and occurred in the daytime, with terrifying hallucinations, visual and auditory. It became necessary to intern him, owing to his violence. He became calm and entirely lucid, then at the end of a fortnight he had a new fit of frenzy lasting for four days. Fresh apparent cure. Invalided a second time and sent back to his family at their own request, he had, during the night following on his return home, a more violent attack than any of the others, in the course of which he nearly killed his wife. He was again put into confinement.

Here, then, is a case in which the toxi-infectious element was of no importance in comparison with the emotional and with insane predisposition. I have given it in full detail because the perfect lucidity in the interval between the attacks might lead to the belief that these were simulated. As a matter of fact the man had been sent back from the front with the diagnosis of simulation. These cases are rare, but not aberrant. Note that, in general, alcohol has nothing to do with them.

§ 8. Diagnosis

To be practical, the study of the mental confusions of war should have regard much less to the psychiatrical classification than to the prognosis and the therapeutics. The classification is easy: the practice may be extremely difficult.

The symptoms of confusion are often enough taken for those of dementia, and among others, for those of general paralysis. This mistake is sometimes very excusable. There are many cases of confusion—and I do not now speak of those who have been shell-shocked—who have exaggeration of the reflexes, tremor of the hands and tongue, and unequal pupils. In such cases, in default of anamnesia, only observation in a neuro-psychiatrical centre will solve the difficulty.

Often one meets with great difficulty in distin-

guishing excited mental confusion from an attack of mania or of polymorphous delirium.

Besides the physical signs, which are lacking in the last two cases, the distinction may be made by the greater incoherence of the confusional ravings, and by the intellectual torpor which exists even when there is initial excitement. As we have seen, the diagnosis of the fatal acute delirious mania of rabies is a bacteriological diagnosis, for the clinical aspect of rabies is nothing but an acute delirium. The depressed condition, which will soon be considered, has many affinities with mental confusion, either because the two different conditions are associated, or because, notably in the quiet forms, it is not easy to distinguish the clinical signs of one from those of the other type. This peculiarity is due to the fact that the depressed conditions are not an autonomous illness, always the same, any more than is mental confusion. The two classes of cases have, as has already been pointed out, a common point of departure : the preliminary phase of fatigue, cerebral torpor, and instability, this last sign being more marked in the depressed conditions.

Automatism, which plays so great a part in confusion, is still more recognizable in neurosis, hysteria, somnambulism, and even epilepsy. That is one of the most delicate points in diagnosis, all the more so that, in the army, many cases of confusion are affected in relatively light ways, and are easily taken for neuropaths. Assuredly there are close resemblances between these different secondary states. But their treatment differs, and it is advisable to seek for the other symptoms, and to avoid, for example, subjecting a case of confusion to psycho-therapeutical experiments, doomed to failure.

§ 9. Treatment

The treatment of mental confusion is both pathogenic and symptomatic. For patients from the front, the first indication is *rest*. Even for those in whom

the emotional element in the causation is but slight, the noise of the guns is a condition most unfavourable to recovery. Therefore, except for the very light cases, destined to recover in a few hours or a very few days, transfer to the rear, as far as possible to a quiet centre not bombarded by aviators, should be effected. If the symptoms are serious, and call for a treatment of some length, the case should be transferred to an army psychiatric centre, which should be fitted up for complete treatment.

There, or in a base hospital, if the army centre does not suffice, the indications still are *rest* and *disintoxication*. The patients should be put to bed, isolated as far as possible from one another, and left in silence: sometimes, when there is excitement, in semi-darkness, or in a room lit only by a blue light. Prolonged baths will quiet the excitement and restore sleep. If these fail, chemical sedatives may be employed, but with extreme discretion, so as not to augment the toxic condition.

Above all, it is necessary to pay attention to the alimentary canal, to clear it to begin with, and afterwards to restore its functional activity. These cases of war mental confusion are exhausted, and rapidly grow thinner; inanition is a complication which must be avoided. Wherefore, after the purgatives use tonic preparations: nux vomica, bitters, kola, quinine.

The mouth and teeth should be perfectly cleansed: abnormal digestive fermentations are harmful in every way. If the diuresis is insufficient, we should try to restore it by infusions or diuretic waters, given between meals and in small quantities, so as not to increase the gastric atony. If this persists, a good method of conquering it is to wash out the stomach with a tube, following the method of Régis. Even in a case of severe poisoning it is better never to bleed the patient; in these confused cases there is anæmia with destruction of the blood platelets, and bleeding would aggravate the condition.

Nevertheless, this general direction may be invalidated in certain special cases, particularly in those of gas poisoning. In such a case we should, of course, act in conformity with the special rules required by it. Sometimes the restoration of mental energy is hastened by the administration of a fairly strong dose of *digitaline*, twenty drops at least of the solution to the thousandth of a gramme of crystallized digitaline, a dose which should only be repeated at the end of three days. We should not prescribe either caffeine, which excites the patients too much and interferes with sleep, or theobromine, a powerful diuretic, but one which has the disadvantage of readily causing painful pressure from cerebral congestion.

Very often, and especially when there is a decided infectious element, inhalations of oxygen will have a good effect. Subcutaneous injections of oxygen have also been recommended, but these are perhaps less successful. For the same purpose nucleinate of soda hypodermically (0·50 centigramme in solution at 1/20) produces a sudden leucocytosis which is useful, especially in slow and prolonged cases.

A fairly lengthy convalescence is generally to be expected in the serious cases. We shall see further on what are the military decisions to be considered then.

II.—STATES OF DEPRESSION

These are conditions which clearly show us that, for the most part, the mental disorders of war are only accidents which may be explained both by the circumstances and the predisposition of the patients. In proportion as the war is prolonged, these depressive states become more frequent; they were exceptional at first. This increase in frequency does not mean war weariness, which would, however, be explicable: it is due to the fact that the conditions of the war have changed. It is easy to demonstrate this by examining in turn the nature of these depressed conditions and their diverse varieties.

§ 1. Depressing Circumstances and Vague Anxiety

Psychic and physical depression comes on slowly as a rule, and is due to the combination of many factors. But it may be sudden, and this is the first matter to examine.

Wounds.—The ordinary cause of sudden depression is a wound. Until then the patient has gone on courageously; he has endured the worst privations; once, twice, ten times, he has triumphed, voluntarily, consciously, over supreme horror. He has climbed over the parapet of the trench to rush to the assault. He is slightly wounded, and as yet he suffers not at all, or little; but already the tense will which had borne him to the combat is relaxed. He leaves the spot where he fell, and with his comrades in misfortune who are arriving on all sides, he takes his way towards the dressing-station. The battle no longer interests him. He leaves it like a player who has played his part and whose place is filled, and his thoughts are so entirely fixed on the tutelary shelter towards which he is hastening, that on the road thither he commits imprudences, goes by a short cut, neglects those elementary precautions which months of war had made natural to him, and, as it were, automatic.

And when a little time has passed, and he is in the hands of those who will care for and transfer him, then the depression is accentuated, the springs give way altogether. Brave when face to face with physical suffering, he manifests, when facing moral anxiety, a surprising lack of resisting power. It is he who gives way to panic in the bombarded ambulance, or in the hospital train standing motionless in a station aimed at by enemy aviators.

Thus, the moral factor may be suddenly prostrated, and is ordinarily so through the same occurrence which demonstrated to the patient that he was not beyond the reach of bad luck. This is an indication we shall find again later on.

This depression, to which it would seem that most

of the wounded are subject, is only an incident of a few hours, or at most a few days, with the majority of them. It would never enter any one's head to look on it as a mental disorder; but it should not be looked on as insignificant either, or as a simple failure of courage without any possible reaction.

Surgeon-Major Haury, in an interesting article in *The Medical Press*, has described the "psycho-organical repercussions of life in the war." He has furnished excellent arguments for those partisans of the rapid transfer of the wounded into a zone in which they can feel complete security. There is no doubt that the organic resistance increases rapidly under such conditions, the vital reaction of the tissues is ameliorated, and the chance of shock is lessened. Now if this is so, it is surely because this special emotional state has transgressed in its consequences the affective sphere, and because the whole organism is affected. It is this that explains why we occasionally witness a state of anxious depression following on a wound, and why the mental disturbance of the wounded, which may be an attack of excitement from a dreamy mental confusion, sometimes takes the form of melancholia.

Fatigue, Sleeplessness, Cold.—Wounds would not produce this variable phase of depression if life at the front were not, of itself, and especially in consequence of its duration, a terrible cause of moral depression. All those who have studied neurasthenia, that elementary state of depression in which the organic symptoms dominate, have been struck by the decisive part taken by fatigue when it is coupled with the emotions.

What child's-play are the tribulations of the neurasthenics of the times before the war, in comparison with this state of things, in which complete repose becomes more and more illusory, and in which it is necessary that man should adapt himself to conditions which theoretically would have appeared to be impossible!

Fatigue, which is the result not only of frequent marching under the weight of the equipment on the

worst of roads, but also of the impossibility of undressing, of washing, and of sleeping in accordance with the normal rhythm of human activity, would alone be enough; but there is *sleeplessness* added to it. Most certainly we may become accustomed to anything, and a man will tell you that he sleeps at the front as well as he did at home; but that is only the adaptation of the animal to current necessities, a way of sleeping which deludes the need of the worn-out body, and is in no sense a true repose of the nervous system.

Cold, damp, the frozen mud which encases the person, the *immobility* which benumbs, and is unavoidable, the conditions of installation, the shocks, the odours, also serve to exhaust the power of physical resistance. And this is only part of the trouble.

The Moral Factors.—The permanent *danger* to which we accustom ourselves by a sort of disillusioned fatalism, by which at heart the men are not duped, is one which must not be forgotten. Even in the most privileged units the losses are too continuous, or have been too heavy, to liberate those who still feel themselves to be in the hands of destiny from the memory of terrible experiences. And it is not only the foreseen danger, it is above all that which one does not know of, the perpetual uncertainty as to what may happen to-morrow. It is the awaiting the enemy's attack, which is worse than making an assault; it is the watch in the night, the long hours at the loophole or at the listening post. For the officers there is still another state of mind, singularly depressing for scrupulous minds, that of *responsibility*. Many officers of a remarkably sustained moral, as long as themselves only were concerned, have given way under responsibility. For others, we must also take into account the companionship with less educated and refined comrades: a paltry reason apparently, in comparison with the danger. No; those who suffer from this companionship are those who, more refined or more sensitive, most need to live in the society of their equals,

and to have their support in the midst of the perpetual agony. The consciousness of being separated from those around them by a total lack of comprehension makes them still more lonely.

For all, there is the change of place and habits, the separation from their loved ones, concern on their account, and the uncertainty as to the future: the lost hopes of position, the circumstances, impoverished, or worse. Then there is the waiting, the indefinite length of this war, to which they went singing, with the idea that it would only last for two months. Thus, each autumn the number of cases of depression increases when, with the shortening days, there comes the certainty of a new winter of suffering. There are, in this moral hell, those especially unfortunate who have bad news from home, or who have no news. And when we think of the contingents from the invaded departments, whom the character of this war does not allow to take immediate and violent revenge——

Sexual Influences.—Since the doctrine of Freud and his psycho-analysis have brought into vogue the study of sexual influences on these depressed and anxious conditions, it is no longer permissible not to take them into consideration when we have to do mainly with men doomed to an enduring continence. It is very possible, indeed, that the situation is complicated for a certain number by unsatisfied functional craving.

But the depressing influence of continence should in nowise be considered as absolute or general. Already the greater part of the studies that have been devoted to psycho-analysis have diminished the share of the sexual factor. It all depends on the circumstances. As to the life at the front, at the very least there must be no exaggeration. Chastity that would weigh heavily in a life of security and inaction takes a second place when existence itself is at stake. One thinks of quite other things in the trenches; except, perhaps, those for whom the pain of separation is made more bitter by jealousy, justifiable or not. That is a real factor of depression, because it creates an obsession stronger

than the circumstances of the actual life, and which may produce an injurious impulsion.

The Preceding State.—The fact is there: millions of men have been submitted to this sum of depressing influences, and the great majority have held out. There is, then, an inequality of individual resistance. It is here that predispositions become important. These are at once moral and physical. The moral predispositions are summed up in the *emotional constitution* spoken of by Dupré and already referred to. However, it must not be understood that all emotional soldiers necessarily become cases of war depression. Many, on the contrary, derive from their constitution itself an aptitude for splendid achievements, which uphold and sustain them from the moment of their success. But there are certainly some who are cowards. Most of them are sustained by regard for public opinion. A few, exceedingly rare, cannot conquer their fear, and are practically useless in the firing-line. These are sufferers from infirmity of will, but they are not depressed melancholics. Their terror has nothing in common with that of the mentally affected, who will be mentioned later on.

I have already indicated that there is an emotional constitution acquired by a previous traumatism. This is a frequently repeated fact of experience, and one which it is most necessary to take into account. As André Gilles has said, "Ce qui enhardit, c'est la chance"—It is luck that emboldens.

There are also *physical predispositions.* The state of the digestive canal and of the nutrition, so important in mental confusion, is not to be neglected. The care that has been taken for the provisioning of our troops has done a great deal for their moral. But the circulatory and respiratory organs are quite as important. Without entering into a discussion of the mechanism of the emotions, one may recall their vascular accompaniments. Those with weak circulatory organs, or in a permanent state of hypotension are, taken as a whole, candidates for moral depression. It may be held that

this is only a matter of primarily nervous influences, and that the hypotension is of a neuropathic origin; but this is a supposition that is not of general application, and that is, at the very least, doubtful in many cases.

Similarly, *tuberculosis* exercises a certain depressive effect. There are many tuberculous men at the front, only slightly affected to be sure, bearers of slight lesions, but slowly poisoned, having perhaps localized lesions in the suprarenals, or those pleuritic points which interfere with thoracic expansion, and which are distressing through the mere physical discomfort they cause.

Vague Anxiety. Besetting Ideas. — The preceding etiological considerations have their importance. The men we send back because of their state of depression are affected with all of them, and it is necessary to take all of them into account in order to cure the patients and to set them going again. It is owing to these circumstances—of which, I once more repeat, the main point is their duration—that, among those with the least resisting power, or the most severely tried, there arises little by little a painful feeling of insecurity, and then of vague moral suffering, which is not a fear of death or of the risks of battle, but something different. The patient, like the sufferer from confusion, first passes insensibly from a normal emotional condition and clear reasoning power to a peculiar state in which an affective indifference is combined with a general feeling of anxiety, and also with an inability to reason out his ideas as he formerly could. Slowly, certain parasitical ideas become developed in the field of his mind. Sometimes they are quite reasonable ideas, real anxiety about his family left far away, for instance. Sometimes the ideas are absurd, or at the very least exaggerated: some scruple, the fear of responsibility, or the opinion of his comrades. The man "makes his own ideas," and these become more and more tyrannical and dominant. According to his beliefs, his religious habits, and the turn of his mind, according also to the chance of circumstances, his

ideas may take a mystical turn, or they may remain practical. But even when religious, they take a pathological character. Confession to the chaplain and receiving his absolution will not calm the patient's scruples. These are not the reactions of a fervent spirit, but the anxious disquietude of a sick man.

Night, which veils all real objects from view, delivers the mind over to the fantastic creations of the imagination; night at the front, full of mystery and menace, develops the besetting idea, and above all, the anxiety. When this is established, it makes a parallel attack on the general condition. The man no longer eats, is constipated, auto-intoxication sets in, and he grows weaker. Sometimes he retires into himself, or he may present himself for examination. But he cannot give an account of himself; he suffers from nothing precise, he does not himself know what weighs on him. He certainly suffers from anxiety, but he expresses it by the physical impression of a weight on the chest, which corresponds to nothing observable by examination. With encouragement he might, perhaps, be got to tell of his terrors, but one does not confess to being afraid at the front. And that is why, unless he falls into the hands of a surgeon well on his guard, he is taken for a malingerer, and receives no encouragement to return.

In that case it goes on for a longer or shorter time; the chance of a relief, of a leave of absence, or the departure of an officer who did not understand him and of whom he was afraid, may give the sufferer an opportunity of coping with it, of pulling himself together again; or else he sinks into its quicksands, and if he is not discharged in good time, goes on to impulsions, or delusion.

§ 2. Anxious Impulsions

The first stage of these states of depression is in the main a psychasthenic condition. There is the psychasthenia of anxiety, of the besetting idea, and morbid

doubt, which we shall meet with again later on; and also useless activity and *impulsions*. A man who is in this unstable condition is very susceptible to suggestion. He has also the desire to escape from his obsession, to break away from it. In this way there are formed different kinds of impulses.

A *suicide* has no need of prolonged suffering and of a rational disgust with existence to tempt him. Most often it is the result of a sudden impulse, of obsession, especially under the influence of a sleepless night. Dawn is the dangerous time. We know the importance of auto-suggestion and of example in such cases.

Voluntary Mutilation.—The self-inflicted shot-wound in the left hand, so very serious as an example, but the frequency of which has perhaps been exaggerated, may very well be the result of a sudden impulse in a man suffering from depression, who had no conscious desire to get himself fraudulently dismissed.

Running away is much more common. We shall refer to it in the medico-legal chapter. I only wish to remark here that these anxious cases are cases of obsession, all the more interesting since they may be quite unconscious. Here we enter the obscure region of neuro-pathology, on the boundary, as it were, of several states that we might take to be very remote one from the other : such as mental confusion, psychasthenia, epilepsy, and somnambulism. I tried several years ago to show the connection there is between these different states, notably with respect to obsession. The war has supplied new arguments for that thesis. Already, with regard to mental confusion, we have seen the links between simple sleep, sleep troubled by nightmare, somnambulism, and hallucinatory dreaminess.

We have seen, after a prolonged bombardment, the patient fall into that strange torpor which scarcely allows of the existence of more than a kind of automatism. Assuredly, in such a case, depressing moral influences are mingled with the nervous fatigue.

What we must retain for practical use out of all this is that the impulsive actions of these anxious cases

are connected with a kind of "second state," that they are not necessarily insubordinate acts amenable to all the rigour of the military code, nor those of a confirmed madman fit for the lunatic asylum. The circumstances of war are, in the highest degree, those in which this automatism is developed.

§ 3. Delusions of Anxiety

I purposely employ the expression "delusions of anxiety" or "apprehensive insanity," instead of that of "melancholic insanity." Anxiety is a characteristic of all the sufferers; even in the quiet forms of melancholia, the dull ones, if one may call them so, we find, on questioning the patient, that there is some idea of an anxious type which has an inhibitory action on the cerebral functions. At least, such is the case in those who arrive from the front. And it is just these that it is important to watch for; and it is specially for their sakes that this book has been written.

Now there are men who go beyond the preliminary form of vague misery, and who begin to have delusions. The first apparent sign of this form of insanity is the general attitude: the man isolates himself more and more, his expresssion becomes both inert and absorbed; he appears to mistrust his comrades, or at least to be very reserved with them; or he may, on the contrary, confide to some intimate friend the fears and scruples which possess him.

These delusional ideas have a common causation, one which enables us to recognize how they are coloured by circumstances. This psychological basis is fear, not of the enemy, but of the authorities—of military discipline. It is the dread of being a defaulter, of being arraigned before a court-martial and shot. Nearly always this is the first idea, any others coming later.

So the sufferer from delusion of anxiety awaits his punishment; and all the incidents of his military life, or of life in the hospital, are interpreted by him as being

connected with his execution, which is either near at hand or only temporarily postponed. Often this idea attains to its most acute maximum without any other delusional idea coming in to explain it. The patient knows they are going to shoot him, he does not know why. This is in some measure the typical schematic case; but usually the delusional ideas are less *torturing* and more varied.

The first idea of capital punishment, or at the least of a heavy penalty, having been implanted in the mind, the patient explains it. He says to himself: "If I am to be punished, it is because I have committed a fault, or because I am an incapable." Hence arises the idea of culpability, or unworthiness, the first being the more common. There is no need to dwell on the variety of offences which the patients confess they have committed: negligence in service; lack of respect towards a superior, a venial fault, yet one which led to the death of a comrade; lack of courage; secret correspondence with the enemy. Thus arise these self-accusatory ideas, the consequences of which are evident when they are expressed to comrades or officers totally unprepared for critical psychology, and whose duty it is to proceed without lenity against all faults and failings.

Fortunately, these delusional symptoms are often preceded by a period during which the patient shows signs of abnormality. But these self-accusations may be the first outward sign of insanity.

The tenacity of these delusions is extreme. No psycho-therapeutics take effect, even when the delusion is limited to one absurd idea, the nature of which one would imagine to be demonstrable to the patient by one simple and decisive proof. They are not necessarily lessened by taking the patient away from his occupation. Even in the rear zone, where infractions of discipline have much smaller practical and penal consequences than at the front, the delusions often last some time. I had in my department one G.V.C., aged forty-five, prematurely senile, and in whom the

alcoholic antecedent certainly operated, as is so often the case in this class of mobilized men. After a phase of general anxiety, he exhibited the delusion of anxiety of being recorded as a deserter. It was thought wise to give him fifteen days' leave. But he spent it in returning to his post to report himself, fearing more than ever to be held to blame.

These delusions of anxiety have in certain cases a mystical character, but less often than one would expect, considering the extreme peril in which the men find themselves, and the frequency and strength of their religious sentiments. These mystical tendencies usually manifest themselves in an acute form, in patients already fanatical in ordinary life, as demonstrations and gesticulations of a somewhat theatrical character.

It is unnecessary to dwell on the infinitely varying psychological details of these delusional states. We must bear in mind that these people, like all those suffering from melancholia, have physical maladies also, due to auto-intoxication and vital slackening (lowered temperature, arterial tension, diminution of the secretions); but these disorders are less evident than in the confusional cases, and will have to be looked out for.

When a patient has been depressed for some time, circumstances do much to promote the delusion and to determine its aspect. I have seen several cases of this among officers who have had ill luck in their career, or their service, or rather who had not gained in some given operation that which they had hoped to do. It may be the officer commanding a battalion, which in the course of an attack has been checked by obstacles he could not foresee, even though he himself had reconnoitred the ground on the previous days beyond what was required of him by his duty. Or it may be the officer of a unit which has reached its proposed goal, or fully maintained its position, but who reproaches himself with the heavy losses that were inevitable. Still oftener it is officers who have been prisoners. The greater number of those who have

been repatriated as insane, and henceforth unfit for service, were, apart from general paralytics, sufferers from delusions of anxiety, in whom the cares and sufferings of captivity had excited considerable mental disorder. Likewise among the men, especially if their consciences reproach them with having surrendered too easily (which, however, is quite exceptional) the fear of a court-martial on their return may provoke a delusional reaction.

Often, also, the delusion of anxiety has a local cause: it is originated by a wound, and centres upon this. I have several times had in my department men who, haunted by the idea of the punishment inflicted on self-mutilators, have, with a troublesome persistency, accused themselves of having given themselves wounds of which the origin was certainly natural. In their own interest, and to safeguard their future, I have, if the delusion persisted after they had left the hospital, instigated inquiries, and have proved their innocence beyond doubt. It is needless to add that they were not convinced by any of the proofs which were given to them.

In impressionable patients, the delusion of anxiety may appear as soon as the man is wounded. Many of the wounded who display excitement, and tear off their dressings, are under the dominance of a paroxysm of anxiety which came on at the same time as the general infection. This is another of the numerous points of contact between the states of depression and the states of confusion.

§ 4. Fatal Acute Delusions of Anxiety

The bond between anxiety and mental confusion appears again in the following fact, of which I have at the present time at least ten genuine cases, and which it is necessary to be acquainted with. After a period of preparation, which may be either a delusion of anxiety of medium intensity, a simple state of depression, a vague sadness without delusion, or even

an absolutely normal mental condition, an extreme anxiety comes on, with tremors, panic terrors, oppressed respiration, and rapid pulse. The features are distorted, refusal of all nourishment is at once absolute, restlessness is incessant, and there is no sleep. Sedatives have no effect, and in two or three days the patient dies of syncope.

This is an acute delirious mania, exactly similar in its course to that of which we spoke in connection with mental confusion, but it is a distinct form of insanity, co-ordinate from the psychological point of view, to begin with at least, and essentially characterized by extreme anxiety. The patient seems less toxic or infected than in the other acute insanities. The temperature remains normal, or is only slightly raised towards the end. The impression it gives is that the man literally dies of his anxiety. There is no reason to be inordinately astonished at this. The sudden death by syncope of melancholics has long been familiar; here the same thing very probably happens from a lesion of the bulb, unless the pathology of the vaso-sympathetic system, which is still imperfectly known, should succeed later on in throwing fresh light on the subject.

This syndrome of fatal anxiety does not seem to be well known in France. It answers probably to the fatal anxious psychosis described by Wernicke and Kraepelin; but the cases that I have met with seemed more remote from mental confusion than those of the German authors, who found that there were signs of acute confusional insanity, confirmed after autopsy by the finding of distinct cellular lesions.

§ 5. Transitory Delusions of Persecution

Those psychiatrists who reverence correct classifications may be astonished at the mention of the delusion of persecution in a chapter treating of states of depression. But there is a practical question at issue here which calls for some elucidation.

Every one knows that persecutory mania with hallucinations of hearing is one of the most chronic of the varieties of mental disease. There is not in this respect much difference as regards prognosis between the polymorphous mania of degenerates and the chronic mania of a systematic evolution. But when one can observe, as I have done, first in my sorting-out centre, and afterwards in the asylum, a certain number of these persecutory cases discharged from the army, one cannot but be struck by the number of those who recover. One's first thought is that there must be an error of diagnosis, but when one closely examines the patients and their papers, this explanation is found to be too simple. One may with good reason suspect alcoholism in many of them, but even if it were proved that it may simulate persecutory mania, the clinical fact would no less hold good.

The question is cleared up when we refer to the classical treatises. Ever since Lasègue and specially since Magnan, we know that persecutory mania comes on slowly. The patient begins with a period of general disquietude, which is really an indication of a psychic depression, and in the course of which illusions and delusional interpretations appear, the repetition of which will result in hallucinations later on.

This peculiarity, which allows us to catch a glimpse of a period during which treatment might perhaps be efficacious, has not prevented the generality of alienists from looking on the passage through the later stages as absolutely inevitable, exception being made of certain special cases. However, of late years we have gained more knowledge of the initial period, notably through the work of Pierre Janet on psychasthenia, and by studies, such as those of Arnaud, on the transition from psychasthenia to insanity.

I had collected for some years a certain number of observations, in which either some external circumstance or some organic physical malady, supervening on a mind already predisposed to psychic depression, had provoked delusional interpretations, or even

hallucinations, which in some cases had been cured, while in others persecutory mania became established. One may infer from this that the doom to which this persecutory delusion sentences the patient is not without appeal, and that if proper care can be given in good time, the prognosis of the affection may be modified. Now this is just what happened in cases such as the following—

C., at the front from the first, evacuated in May 1916, for persecutory mania, is not feeble-minded, his intelligence may even be above the normal. He has had a fatiguing existence in trying sectors, he is worn out and thin. After a period, which he describes well, during which he felt "all anyhow," hallucinations made their appearance. *They had an anxious origin.* His comrades were jealous of him, he said, and accused him of making signals to the enemy. Then they insulted him, magnetized him, and spoke to him from a distance. "I am quite sure I am not mistaken," he replies to a doubt expressed before him; "when I went alone on fatigue duty, or when off duty I went for a walk along the road, they talked to me and insulted me, and when I turned round there was no one there. And there was no tree or hole in which they could have hidden themselves."

In him the hallucinations soon begot a state of self-satisfied complacency, which mingled with the ordinary suspiciousness of persecutory mania. The delusion now referred, not only to the persons, but also to the motives of their persecution. The patient, quiet on the whole, was not far from having defensive reactions. He was treated by rest and disintoxication, as if he were a confusional case, although the organic signs were at a minimum; then by reconstituents as in melancholia. Little by little his hallucinations became less pronounced, and at the same time he began to have doubts as to their reality. Then he recovered completely.

S., age 35, was formerly a moderate drinker, without

mental impairment, sent to the rear the first time in 1915, for a state of melancholy and slight fatigue, which lasted only fifteen days, and permitted of his return after seven days of leave. Sent back again in 1917, for persecutory mania with hallucinations of hearing. These hallucinations are incessant. He has also hallucinations of the sense of smell, but none of sight. He hears his comrades call him " filthy fellow," he inveighs against them, becomes violent with them, and tries to strike them. *For him also the originating cause was an anxious idea.* " Because I committed a peccadillo formerly," said he, " they treat me as a filthy fellow." He recognizes the voice of one C., who was a member of his squadron at the front, and who, in his mania, plays the part of principal persecutor. Here also the cure was complete in a few weeks.

How can we explain these somewhat paradoxical facts ? As a rule the patients are probably men with a marked emotional constitution, and therefore predisposed. They acquired their mental malady under those circumstances, so depressing from the point of view of moral, on which I laid stress at the beginning of this chapter. These circumstances made them pass through the first stages of persecutory mania much more rapidly than is generally the case. Transferred as soon as their disorder made its appearance, they were under observation, and cared for in surroundings completely different from those in which they were taken ill. Now the prolonged persistence of the same causes is the true reason of the incurability of persecutory mania.

With respect to the mechanism of these persecutory ideas, I have already shown the suggestibility of patients during the phase of vague anxiety. Then, even as in the night a leaf blown by the wind may provoke an alert, so may the pleasantry of a comrade, or a word in a letter, be the originating cause of an entirely morbid process.

The passage also from anxiety to morbid doubt has been already noticed, particularly by Raymond Mallet,

who has observed these hallucinations also, or, as he calls them, these pseudo-hallucinations. In reality, when one observes the patient for some time, one gains the conviction that it is really a case of true hallucination. The interest of the matter lies in this, that these cases modify our notions as to incurability of chronic delusions, since some of them at least can be cured. If these facts are confirmed, as is likely, they will be valuable for the light they throw upon persecutory mania. They clearly show that it is in a depreciation of the attention, of the will, and of the critical sense that this mania begins. Hallucination is formed only late in the history of the case, after the patient has had illusions, impressions of having already seen or already experienced, and errors of interpretation. It is a resultant. In ordinary life, in which the morbid causes weigh much less heavily, it only comes tardily. In the life of the war it comes on very quickly.

These persecutory manias are thus originally and essentially states of depression. It is because of that that they are in their proper place here. They are like those melancholic persecutory manias studied by Régis, at least in the cases I have observed, and distinguished from them by two signs: the frequency and importance of the hallucinations on the one hand, and the lack of suicidal tendency on the other. Whereas, ordinarily, when a melancholic has a persecutory mania superadded, he has it without hallucinations, and *per contrà* has suicidal ideas. We may say that the victim of pure persecutory mania never commits suicide.

§ 6. Diagnosis and Prognosis

What has been said shows the difficulty of estimating justly these states of depression. At their beginning one is tempted to raise the moral of the men by energetic methods. That answers sometimes, but not always; the real sufferer from anxious depression is not idle or a coward; he does well all he can do. One is all the more inclined to believe that he lets himself go, since

his condition often changes perceptibly during the course of the day. The worst moment is in the morning at dawn, after a night without sleep in the mysterious and hostile darkness. In the day, at the end of the afternoon, the patient is better. Once the clinical manifestations, obsessions, impulsions, and delusions are well established, the diagnosis is simplified : as we have seen, it is partly medico-legal. But we may be in doubt whether it is a case of mental confusion or of depression. The difference is more systematic than practical. There is nearly always some toxic constituent in the state of depression, even as there is a more or less important moral element in mental confusion. In all these cases treatment in a quiet place is necessary. However, the diagnosis modifies the prognosis, and it must be admitted that, as a rule, a state of delusional depression will last longer than an attack of mental confusion.

To estimate the probable length of the state of depression, one should take into account any physical disorder that may aggravate the situation : a noticeable diminution of the secretions and excretions, refusal of food, coldness of the extremities, lowering of the central temperature. The maximum of these disorders occurs in the type with stupor ; it does not appear to be very frequent unless some important element of mental confusion is superadded.

One should carefully examine the circulatory system of depressed and anxious cases, remembering that sudden death from syncope may occur, even apart from acute delirious mania ; and also that circulatory disorders predispose to the anxious state. Among officers particularly, one should watch for any commencement of arterio-sclerosis. It is not impossible that tobacco, which is so much used at the front, may be distinctly noxious in certain cases.

§ 7. Treatment

With few exceptions, all patients attacked by marked depression, having reached the phase of besetting ideas,

habitual sleeplessness, and disturbed nutrition, should be transferred from the front zone, and placed in repose and under observation for several days in a quiet place. If the delusional ideas are pronounced, the patient should be sent to an army centre of neuro-psychiatry. There are mistakes to avoid: in the presence of simple depression do not think that tonics (strengthening diet, alcohol) will do marvels; they will complicate the case. On the other hand, do not have too much confidence in opium, useful sometimes, but whose euphoric effect in cases of delusions of anxiety has been exaggerated. It adds a fresh intoxication to the disturbance of the general condition, and should be looked on as a medicament for occasional use, rather than for prolonged treatment.

Repeated purgations, and a sojourn in a comfortable bed, after repeated baths and a complete toilet, will do more to restore calm.

This is the urgent treatment. If the case is serious, the treatment properly so called should be carried out at a centre possessing the appropriate resources.

It will be exceptional in a casualty clearing station to have to resort to forcible feeding in the case of a sitiophobic melancholic. Indeed, the stomach-tube should not be passed till as late as possible, since the patients accustom themselves too easily to this way of being fed. If there is risk of starvation, one should introduce by one nostril a softish rubber tube, fifty to sixty centimetres in length, after having coated it with vaseline or sterilized oil. Care must be taken that it does not double up in the back of the throat, and above all does not pass into the trachea.

The food should be introduced very cautiously (milk, soup), as also the medicaments. In withdrawing the tube the aperture must be stopped very carefully, by pinching it, to avoid the falling of particles of food into the larynx.

In the cases of anxiety one should be on the watch for any suicidal ideas, and any cases that are suspicious in this respect should be evacuated immediately, less

perhaps for their own salvation than for the avoidance of the contagion of example.

III.—NEURASTHENIC CONDITIONS

Neurasthenic conditions are states of depression, and consequently might have been placed in the preceding group. But these patients are sufficiently different from the melancholic and anxious cases to be separated from them. Many neurasthenic conditions are transitory: others are lasting. The word Neurasthenia, which the public, even the medical public, employs in such differing meanings, is very rarely seen on hospital notes, unless it is as a euphemism which serves to designate serious mental disorder, such as melancholia.

The greater number of neurasthenics are evacuated for general fatigue. They really are tired persons whose illness consists of an impression of painful fatigue, and especially of an incapacity for the daily recuperation of lost strength by means of food, rest, and sleep. Psychologically they may resemble confusional cases in the difficulty they have in making the least physical or intellectual effort, and by the sluggishness of their attention, the inaccuracy of their memory, and the impossibility they find of coming to a rapid decision. They might also be taken for "anxious" cases, when the discovery of their impotence alarms, or renders them desperate. This is the case with officers who, after having been equal to all circumstances, feel themselves incapable of fulfilling their duty. Thus neurasthenia borders on mental confusion and anxiety. But in neurasthenic cases these two pathological conditions are only possible terminations. The true neurasthenic is extremely conscious of his condition; he has not the torpor of the confusional cases, and at the same time his ailment is more physical than that of the anxious cases. If he could rest, he would be cured.

Some years ago, when Congress and the medical

Societies were discussing the nature of neurasthenia, many eminent men maintained that its origin was entirely psychical and emotional. To-day, they should better understand that emotion causes mental depression rather than neurasthenia.

Then are the neurasthenics of war in no way predisposed from the nervous point of view? Yes, and one of the best proofs that can be given of this is that they are nearly all officers or non-commissioned officers. Neurasthenia, then, is often an illness of the relatively educated nervous system, and also of those people who have responsibilities. But physique plays its part. That is easily understood. There are in effect, if we may generalize a little, two principal types of neurasthenics. The one corresponds with those men, still young, who have never been physically robust. Energetic, by fits and starts, they hold out for some time, and then give way completely, often because of some digestive incident which has interfered with their daily recuperation of energy. For example, one fine day, an unimportant alimentary intoxication has given them a touch of enteritis. They do not rally from it. They have often some latent organic defect: a former tuberculosis not fully extinguished, or a suprarenal insufficiency, or possibly the liver does not act well. They are, as a general rule, "hypotendus" and "hypophysiques," according to Martinet's data. The other type, to the knowledge of which Maurice de Fleury has specially contributed, is that of the "arthritique uricémique hypertendu," and prone to congestion. The patient is in a permanently toxic condition. He is relatively rare at the front, owing to the conditions of life in the fresh air. They throng the offices at the rear. Sometimes the nutritive disorders are difficult to discover, though important, as in the case of a patient of St. Dufour and Levy's, who had 2 gr. 45 of urea to one litre of serum.

But there are other types of neurasthenics in whom it certainly seems that nervous weakness is the essential factor, such as some peasants, who seem well enough

physically, and have evidently been accustomed to hard and continuous labour, and who after being in the war some time are worth nothing, complaining of extreme fatigue and appearing really incapable of endurance. They are generally unrecognized cases of anxiety, in whom a more or less conscious emotive condition exercises an inhibitory effect on the general activity by producing erroneous ideas of illness, and hypochondriacal preoccupations. A more important group is that of the traumatic neurasthenics. It might have been feared that these would have been decidedly more numerous than they have been. As a matter of fact their number has been inconsiderable.

Among those wounded who display symptoms of neurasthenia there are several cases to be distinguished.

(*a*) There is a traumatic cerebral lesion. The neurasthenic phenomena are then connected with organic symptoms, or with hysterical manifestations. We shall return to this subject later on.

(*b*) Cases in which there is a wound not directly injuring the nervous system, but seriously affecting the general system.

(*c*) There is no apparent wound, but the phenomena are consequent on the explosion of a shell or a mine. It is the syndrome of shock, to which reference will be made later on.

(*d*) There is a wound or a contusion of the extra-cerebral nervous system. Here there are two hypotheses : it may be a matter of purely psychical phenomena, analogous to traumatic hysteria ; or, on the contrary, the occurrence of the wound may have left organic consequences behind it. Certain localizations of wounds are interesting in this respect. I specially noticed a man pierced right through the abdominal region by a bullet which had not touched the spine, but which had probably injured the sympathetic nervous system, and perhaps a supra-renal. It left him in a well marked neurasthenic condition with arterial hypotension. Likewise an officer and two men, wounded by shot at the base of the cranium, not seriously injured, but there

was probably contusion of the cervical column. They had a special feeling of weakness, with giddiness and unstable equilibrium, very characteristic; but there was no indication of organic localization.

It will be understood that I leave out everything which, in these neurasthenic conditions, depends more or less consciously on exaggeration. The affinity between the casualties of labour and those of the wounded in the war will be studied in the medico-legal chapter.

Thus there are, either from exceptional over-fatigue, or from the circumstances enumerated above, simple states of neurasthenia, with a minimum of mental participation. Their progress depends much on the circumstances and their treatment. Some are protracted. It is not always easy to recognize them, especially in the group of "uricémiques hypertendues," in whom the neurasthenia chiefly manifests itself by amnesic phenomena, and a difficulty in doing any mental work. In the case of officers, especially those between forty and fifty, the intellectual torpor, linked with the setting in of arterio-sclerosis, often makes one apprehend general paralysis.

The diagnosis is full of difficulties, which may lead even the most experienced to make mistakes, and which sometimes only time can rectify. It is all the more difficult when at bottom the diagnosis is perhaps in certain cases only a prognosis. It does not appear to be proved that, between the "neurasthenic" condition of a man of forty-five, syphilitic for fifteen years, with hypertension, who was cured by rest and a hygienic treatment, and the beginning of a slowly developing general paralysis, there is any essential difference. General paralysis is a condition of failure of cerebral nutrition: it is not impossible that before this final stage there is another, during which these cases are still curable.

In any case, specific treatment should not be employed at the outset. As we shall see further on, it is dangerous for those brains which easily become

congested. One should evacuate those neurasthenics suspected of general paralysis, give them complete rest and disintoxicate them.

As for those cases of neurasthenia brought about by over-exertion, physical fatigue, bad digestion, enteritis, etc., they are medical patients, to be cared for as such, and generally within the army zone itself. The treatment should comprise, as far as possible, putting the teeth into good order, an important factor in these cases.

IV.—SHELL SHOCK

Up to the time of this war, when we spoke of *shock* of the nervous centres, we meant phenomena consecutive on a direct shock to the head or the spine, which had not produced any perceptible wound. Such is the cerebral condition following on a fall from a horse on to the head, where there is no fracture; or a more or less complete paraplegia caused by contusion of the lumbar region. But despite some interesting studies in anatomo-pathology, and in experimentation, we scarcely knew in what these lesions consist. In especial, the precise and close study of the phenomenon, such as had been made by Duret, by Polis, and several others, had been upset, we must admit, beyond all anticipation by the operation of the law of 1898 regarding labour casualties.

In industry it happens so often that a shock brings about the conditions of concussion without producing any wound, and there were so many conscious or unconscious exaggerators among the casualties, that the doctors inevitably lost themselves among the crowd of cases over which scientific control was impossible. Just as formerly actions for damages had reduced the symptom of concussion through a railway accident, "railway-spine," to hystero-traumatism; so it was pretty well accepted by current opinion that injuries of the nervous system caused by shaking or shock were, when they did not produce any well defined and

localized lesions, only manifestations of a neuropathic or alcoholic kind.

From the earliest battles of 1914, the employment of heavy artillery has changed the conditions of the problem, without in any degree furnishing its solution. We were confronted by cases of a new kind, often exhibiting serious symptoms, but without any apparent wound. The time was not propitious for making detailed and continuous observations, for as yet there were no special centres. Each one interpreted what he saw according to his medical knowledge and his personal temperament, and it was but slowly that this chaos was brought into some order. We learned that men who were in the near neighbourhood of the explosion of a shell, of a mine, or of a trench mortar, will develop a syndrome, variable, but having certain common features, in which both physical and mental symptoms participate. Concerning the clinical picture, agreement was easily attained. After many doctors had failed to recognize or had doubted the phenomenon, it became at length common talk. But controversy still persists as to the nature of the injuries. Some think that the organic element predominates, others the neuropathic. This opposition is not only a matter of doctrine, it corresponds to a clinical distinction, some patients being distinctly emotional rather than commotional.

For greater clearness of description, and so as to appreciate better the pathogenic evidence, it will be expedient to study separately the immediate symptoms and the later phenomena.

§ 1. Immediate Symptoms

The immediate symptoms have been very well described, notably by du Roselle and Oberthür. My colleague Grandclaude has studied them in a thesis of very vivid descriptions, and in unpublished notes, from which I shall borrow freely.

A. *Common Type; the Shell-Shocked.*—A big shell bursts, usually in a hollow, or in some limited space in

which repercussion of the waves of pressure takes place. Some men are near the explosion, not wounded, and not even thrown into the air, or touched by falling fragments. They remain where they were, thrown down if they were upright, sometimes rolled over like a shot rabbit. Some have lost consciousness, but not all, and some only for a very short time. They are *inert*, their faces have suddenly become atonic, as if all their power of expression had been annihilated at a stroke.

They remain lying down, crouching, or curled up in uncomfortable or unnatural attitudes; their muscular relaxation is general, their muscles are slack, their sphincters relaxed. There is no actual paralysis, but their movements are clumsy, inaccurate, and inco-ordinated. The general sensibility is much diminished, and when the intellectual obnubilation permits us to get into communication with the patient, it is ascertained that the sensorial acuteness is greatly diminished. Some, who were able to state precisely their sensations, told me of a feeling as of fog and sudden darkness before their eyes.

On the other hand, the tendinous and cutaneous reflexes are generally quick and sharply exaggerated. Often one may discover, as perhaps du Roselle and Oberthür were the first to recognize, Babinski's sign, the energetic extension and spreading of the toes, an active defensive reflex with withdrawal of the limb, phenomena associated with the defence of the opposite side, the symptom of Kernig.

The extremities are cold, and often, as a little later on they begin to grow warmer, this return to the normal takes place in an unequal and irregular manner, one hand, for example, being hot and red, while the other is icy cold. Sometimes a cold *sweat* breaks out, as well as an abundant and viscous *saliva*. The pulse is always small, even imperceptible, and the heart beats rapidly. The state is then one of *collapse*. My colleague, A. Courjon, surgeon of a battalion of rifles in a region particularly exposed to bombardments, managed to

ameliorate very considerably the course of the immediate symptoms by speedy injections of heart tonics, especially of camphorated oil. In favourable cases, in which the circulation is quickly re-established, the heart begins to beat with energy and the pulsation of the carotids is seen at the neck.

When the patient regains consciousness, it is not uncommon for him to complain of a *pain in the abdomen*, or at the pit of the stomach, as if from a blow with the fist; or else in the *thorax*. Then he coughs painfully, with difficulty and an expression of suffering; he spits up a slightly frothy mucus, *stained with blood*. Often also there is bleeding from the nostrils or the ears, or small sub-conjunctival hemorrhages.

The intensity of the phenomena is very variable. There is no need to send the majority of the cases thus affected to the rear, they get on quite well in a field hospital, or at a dépôt of crippled men. During this time the men are *confused* and *giddy*, extremely tired, and they complain of *headache*. If they show no other special symptoms, and if their military duties do not require perfect cerebral soundness, they may rejoin their unit. But it must be remembered that as a general rule they are not cured; and that they remain affected by a special weakness, which will be considered later on.

Besides these fortunate cases, there are others, which should be evacuated, and which we shall meet again at the rear. In these the hebetude is persistent, or complications, such as *deafness* or *dumbness*, occur; or there may be a condition of *mental confusion bordering on stupor*, or even, exceptionally, a true *coma*, from which they will not recover, except under a treatment impossible to carry out in the first line, and particularly by means of lumbar puncture.

Finally, there are the dead—concerning whom there was much hair-splitting at the beginning of the war, some attributing to certain special explosives lethal properties which were really due to the conditions in which the explosions took place, and had nothing to do

with the toxic qualities of their gases, which latter we shall take into account later on.

B. *Emotional Types.*—The initial circumstances are the same, but in these cases the explosion need not necessarily have been very near; though it may happen that it took place at quite close quarters without having had any direct action, the man having been protected by the parapet, for instance. One powerful emotion manifests itself; it is *fear.* Then there are tremors, even screams, and desperate flights, sometimes hysterical fits, or a condition of apparent defect of consciousness which leaves intact the instinct of self-preservation. As with the man spoken of by du Roselle and Oberthür, who, wild and mute, sees the fresh trace of a shell above the door of the field hospital, protests and struggles, and then goes a little farther on to burrow into a shelter on which he fancies the shells will not fall.

These emotional states are sometimes to be observed when the patient arrives into security. By that time they are sometimes assuaged, sometimes, on the contrary, they are exacerbated, taking the form of a convulsive fit, or it may be dumbness, or deafness, or the patient may walk all bent over, either because he was projected or knocked about at the time of the explosion and still feels some pain about the spine, or because of the remembrance of comrades he has seen, who really were shell-shocked.

C. *Contusional Types.*—There are cases on which the shell-shock in itself has not had much effect, but in which there has been some accidental accompaniment, such as being thrown into the air and suffering a contusion of the head or the spine on falling back again; or, what is still more common, having been forcibly thrown against the ground, or the side of the trench, or having been caught under a mass of falling earth. It is sometimes very difficult to make allowance for what is due to these lesions from shock, but in the great majority of cases they are not really serious.

They have their importance, however. Just as with

accidents to workmen the attention of the sufferers is apt to be concentrated on some minute detail, so it is not uncommon for these shell-shocked patients to graft on to some insignificant contusion a whole syndrome of persistency and assertions.

D. *Mixed Types.*—What is most important from the clinical point of view is to realize that very few of the cases are sufficiently clearly defined to belong legitimately to only one of the preceding types. The combination of etiological and clinical elements is the rule, and if it is convenient, from the descriptive and evolutionary point of view, to make these distinctions, it must be realized that they are artificial, and difficult to maintain positively from the psychological point of view. In the thesis of Grandclaude a legitimate shell-shocked man had a distinct emotional reaction : with the gestures of an automaton he places some stones one on the other, makes a sort of shelter, hides behind it, and gazes between two of the stones with the mien of one who is present at some frightful spectacle. He has mental confusion with dreamy state. But we shall find these facts again later on.

§ 2. Subsequent Phenomena

Among those shell-shocked in whom the condition does not end in a few days, and who have to be evacuated, a fresh selection must be made. Some are cured in a few weeks without any important sequelæ ; others will last. In these the clinical type will not be recognizable till after the lapse of a certain time, except in some cases in which the symptoms do not change with lapse of time. Those who recover quickly belong to the two principal categories which I have indicated for the initial phenomena : the simple emotional cases, especially if they are subjected to an intelligent and firm therapeutical treatment, return to their usual state, sometimes even in a few hours ; and many a one among them who had after the shock a maddening reaction will later on show himself a hero. The

protracted cases are not always those which showed the greatest display of emotion.

In slightly shell-shocked cases also the results of the shaking they received disappear little by little. Like lizards when the sun returns, they find again their dormant vitality. They recover their quickness of thought and action, the clearness of their impressions, the facility of comprehension. Not all do so, and even among those who are clarified, many remain extremely susceptible to noise, to a strong light, and to disturbances. Their sleep, too, is restless and precarious, and this is a valuable indication for fixing the time for resumption of duty.

As for those who do not recover during the first few weeks, some have manifestations specially in connection with the general nervous system, and analogous, at least as regards their clinical aspect, to hysterical phenomena (convulsive fits, paralysis, functional impotence, vicious attitudes, dumbness, and deafness). They have a minimum of organic symptoms, and sometimes their mental condition seems perfectly healthy.

With others the mind continues to be profoundly disordered, and they have also physical symptoms connected with the shock. The mental disorders of this period are of two principal types—

A. *Hallucinatory Mental Confusion; Dreamy States.*—On a basis of amnesic confusion, with wandering, and a tendency to automatism, insanity ("war-madness") manifests itself by exteriorization under the form of real scenes, of words, attitudes, more rarely of cries. This dreaminess is quite superposable on that of mental confusion without shock, and it is unnecessary to repeat what has been said. It is not very exceptional, but neither is it very common, for the automatism to lead to lasting somnambulism, such as the repetition each day or each night of the same scene. Such manifestations are ordinarily linked with convulsive fits, and supervene in those cases least subject to mental confusion.

B. *Depressive Mental Confusion with a Tendency*

to Stupor.—In these cases it is the initial inertia which persists. The torpor does not go as far as coma, but ideation is rudimentary, the speech slow, laborious, syllabized, if one may say so, the patient drawing the words from his throat in a monotonous, thick, and broken voice. Few or no nightmares and hallucinations: it is not a psychosis of excitement as in the preceding case, it is a psychosis of exhaustion, as if all the strength had gone suddenly with the blast of the explosion. And, as always in similar cases, from the instant that the normal rhythm of cerebral activity is broken, there is no more of profound sleep during the night than there is of complete lucidity during the day. It is a middle state, which lingers, and progresses very slowly towards recovery, or it may be towards one of those more tardy forms which will be dealt with later on.

C. *Physical Signs of Shock.*—We are now no longer in the precarious conditions of examination in the field-hospital. The patients concerned have been evacuated, if possible straight to some specialized institution. The time for study of the physical symptoms has arrived. With respect to the locomotor nervous system they are less marked than at first, except in those cases which, through the occurrence of some special medullary localization, are purely neurological, and of which a detailed study is out of place in this volume. Later on there is more motive power, the movements are stronger and more exact, the general sensibility returns, though it is still somewhat dull. The tendon reflexes are still exaggerated, but are no longer in the exacerbated state of sensibility that they were at the outset. As a rule the sphincters have resumed their functions. The *pupils* are generally abnormally dilated.

But the *circulatory apparatus* is still disturbed. Here there are two possibilities: In the first there is energetic reaction; pressure is rather more than normal, and the heart-beats are strong and distinct. But this is seldom seen except during the first days, and in men on the road to recovery. The other case is

more common : Persistent low pressure and a heart which gives the impression of being soft and lazy, with periods of *tachycardia* especially in the morning. Generally the *oculo-cardiac reflex* is exaggerated, and that is so from the first. Grandclaude, looking for it about an hour and a half after the shock, noted retardation of 22 pulsations, whereas the normal is retardation of 5 to 10. Abnormally, the reflexes may be reversed, and the compression of the globes may provoke acceleration of the heart.

As a rule, the tendency to collapse still persists. This is proved by subjective phenomena also. Many of the patients complain of a difficulty of breathing, *dyspnœa*, and often after some quick movement, or a slight ascent, tachycardia occurs for several minutes. Often the sound of the *gallop* of weakness may be heard. The veins are swollen by stasis and local vascular inertia, the extremities are apt to be cyanosed and even to become œdematous. A good way to make out the state of the deep circulation is *ophthalmoscopic examination*, which reveals, in the subjects most affected, venous stasis and retinal congestion. Hæmorrhages even have been seen. Perspiration is free, exaggerated, and cold. It is not uncommon for the general temperature to be very low (Guillain).

It is not only the quasi-constant headache with photophobia that testifies to the participation of the central nervous system. In certain cases one is struck by finding the *respiratory system* abnormal, especially during the first few days. It may be either a typical Cheyne-Stokes or some other less regular variety. The same with *glycosuria*.

The examination of the cerebro-spinal fluid may give valuable indications. It is this that, from the beginning, enabled some observers, Ravant among others, to assert the organic nature of some shell-shocked cases. But it may be normal, even where there are symptoms of organic lesion, as Georges Guillain in particular has clearly seen. That does not matter : when one has the instruments, and there is no individual

counter-indication, a lumbar puncture should be made. One may chance to see the fluid expressed under increased pressure, and the patient be relieved by the decompression.

Besides *hypertension*, the cerebro-spinal fluid sometimes shows signs of former hemorrhage (red or yellowish coloration); more often there is slight *albuminosis* with *lymphocytosis*. These last two signs may even be very pronounced, and the consequences of this from the diagnostic standpoint are at once discernible: the appearance of the fluid may lead to a mistaken belief in a chronic process, such as syphilis or tuberculosis.

The test of *voltaic vertigo* is also very instructive. In itself alone it suffices for the detection of doubtful shell shock. Nearly always resistance to the galvanic current, applied to the temples or to the mastoids, is greatly increased; it is not uncommon for the patient to support almost without perceiving it a current of 15, 20, or 25 milliamperes, whereas normally he responds distinctly at about four or five milliamperes; a fact to remark is that besides the vertiginous sensations, the sensations of pain, and even those of taste, are very sensibly blunted. Nearly always the resistance is increased on both sides, but unequally. When the current is strong enough, either the inclination shows itself only on the side of the bad ear, or the worst one, or else the head is only thrown back.

The modification of the voltaic vertigo indicates, it will be understood, a labyrinthic shock. It corresponds with subjective troubles of the same origin, of which, among others, a particularly vivid description is given in an article by Lermoyez in the *Presse Médicale*. This labyrinthic shock may exist without any important cerebral shock, and the patients are then capable of explaining their sensations. At the moment of the explosion they feel stunned; then there is a painful sensation of fullness in the ears, as if there were a compressed pad of cotton wool in the meatus. Then there is a musical sound as of a flight of mosquitoes,

and the patient perceives that his walk is uncertain, and that a quick movement produces giddiness.

§ 3. Later Symptoms

Let us go a step farther. After some weeks of suitable treatment there is a considerable number of shell-shocked cases that are not cured. What is still the matter with them? It is well understood that in some of these cases the phenomena are solely *neurologic:* distinctly organic *paraplegias, amyotrophias,* which doubtless correspond in both cases to *spinal hemorrhage,* which may be of medullary or encephalic origin; *tremors* and *disorders of nutrition.* Agreement has been come to on this point, and indisputable observations, along with autopsies, have attested to the correctness of these interpretations. But, as with the first early symptoms, it is difficult to agree as to the nature and the value of the psychical symptoms. It must be noticed, however, that the organic neurological symptoms are in practice not inconsistent with them. They are very often associated in the same patients.

There is, then, from the clinical standpoint, no *a priori* reason to make a fundamental distinction between the shell-shocked with hemorrhage into the nervous centres, and the mental cases.

For the rest, besides these two types, there are cases which belong to neurology by their symptoms, but in which there is a mental element. These phenomena arise, in part at least, perhaps wholly, from emotion. As for the greater number of emotional cases from the field of battle, they have long ago returned to their corps. At the present time, after several weeks of treatment, there are no longer any non-organic cases in the hospitals, save those that are severely neuropathic, and they are happily rare. Let us first examine the mental types.

Mental Types

A. *States of Neurasthenic Depression.*—The immediate symptoms have completely disappeared; an outburst of mental confusion which appeared to be serious has been cured. The patient, often an officer, whose responsibility necessitates intellectual exertion, has gone on convalescent leave, or has duly returned to his post at the front, or to the dépôt. I purposely designate these three possibilities, for it is remarkable that in these cases it is not the nature of the occupation which creates the trouble. In the one case as in the other the patient discovers that he is not cured, and those about him come to the same conclusion. The patient cannot concentrate his attention, since that brings on a painful feeling of cerebral fullness and a tendency to congestion. Ideas grow confused as soon as an attempt is made to fix them, and the memory is inaccurate, especially for the details of current life and contemporary events.

The patient promptly becomes conscious of his defects, of which he had remained in ignorance while still in the confusional period. It disquiets him. Partly from cerebral weakness, and partly from anxiety, a condition of a neurasthenic kind is established, of which some examples are of a disheartening obstinacy. Physical exercise, which would be invaluable if the disorder were purely neuropathic, is impossible, since any exertion lowers the vascular tension, and increases the distress. Moreover, the action of tonics appears to be unreliable. The patient suffers from persistent headache much more than an ordinary neurasthenic does. Sometimes he has facial congestive flushings, and bloodshot conjunctiva; and these symptoms, which come on by fits and starts, increase the irritable weakness, the general uneasiness, the cerebral incapacity and the nervous disability. Sexual impotence is the rule. Often a special sensibility to light, and still more to noise, helps to maintain this troublesome condition.

This susceptibility is the principal obstacle to an early return to the front.

These disorders are always rather chronic. In any case they will last as long as natural restful sleep has not returned. But sometimes, fairly often even, the progress of the case is of this kind: after the initial phase of mental confusion, which is a psychosis of exhaustion, sound and refreshing sleep is re-established for some time. Then, as the nervous equilibrium is not maintained, sleeplessness returns, sometimes with memories of the war, but not necessarily so. My own impression is, that this is less a matter of imagination and emotivity, than a consequence of persistent circulatory depression.

B. *Mental Confusion and Stupor.*—The state of neurasthenic depression appears to be that to which the relatively intelligent, and at the same time least seriously injured, shell-shock patients are subject. Persistent mental confusion with a tendency to stupor is perhaps at once the portion of the more seriously disordered and of the poorest brains. I have seen very few cases of it, due to shock alone, among the officers and among men of intelligence and culture above the average—this, of course, apart from the acute cases, curable in a few weeks. It is very common, on the contrary, among the shell-shocked soldiers who end in the lunatic asylum on account of the long duration of their disorders. It doubtless is responsible for a somewhat important part of the chronically insane prisoners who are repatriated as unfit for service. It is difficult to determine its prognosis. The patients nearly always arrive with insufficient information, which does not allow of making out the exact share of the shock in their history. It should at least be looked on as very moderate; I have seen recoveries occur at the end of eight months, ten months, and a year. These are rare, and many patients will doubtless remain definitively chronic cases.

C. *Mental Puerility and Precocious Dementia.*—It may happen that, on a foundation of mental confusion,

certain psychological characteristics stand out in strong relief, constituting a distinct clinical type. One of the most interesting in this respect is *mental puerility*. I had the opportunity of observing a very fine example of this for some time, and others have been published by Charon and Halberstadt, Laignel-Lavastine and V. Ballet and Bonhomme among others.

The case that I saw was that of a non-commissioned officer of infantry, aged thirty-five, strongly built, without any known pathological defects, although he belonged to a part of France in which alcoholism is very common. He had given proofs of personal courage before the war, and belonged to the police force of a large town. He had the habit of discipline and a marked sense of duty. According to information received, he behaved well under fire, and there was no failure of moral during several months of warfare. Then, one day, shock, caused by the explosion of a shell quite close to him; loss of consciousness, more or less complete, coma for several days, then extreme mental confusion, bordering on stupor, from which he emerged with difficulty at the end of several weeks, to present the following features : a relative appearance of lucidity; the patient readily recognizes those around him, and knows that he is in hospital. But he cannot tell what happened to him, and is completely out of his reckoning as to time. He has forgotten that he is married and has children, although his family feelings were normally developed. But, above all, he speaks only in a "pidgin" dialect, in a plaintive tone and with a lisping and childish voice. His spontaneous conversation merely touches on the elementary acts of animal life; he remains inert and indifferent. Then he begins to play with pieces of paper and rags, makes himself a doll and paper boots, and is very vexed when they are taken away from him. The directress of the hospital to which he belongs, who is devoting herself with praiseworthy patience to his re-education, has given him a doll, which he nurses and plays with. His play is clumsy; it is much more

like that of the backward imbecile than that of an ordinary child. He has no imagination and no initiative. It certainly seems as if there were a relative "feminization" of the instincts—the toys for little boys seem to give him no pleasure, especially the warlike ones. But it is more especially a total retrogression towards childhood, and one cannot say that there is any real sexual inversion.

The patient no longer knows how to read and write. He does not appear to wander, but at certain moments he has sudden fears, which do not last. For a short time he is more distracted and wishes to run away. But he does not tell of any terrifying vision. Sleep and appetite are pretty good. It took months to emerge from this condition, and it was nearly two years after the shock before the patient could begin to lead an apparently normal existence. Even now he is extremely impaired, incapable of any tiring occupation, or of any prolonged effort of attention. The memory returns slowly. He still laughs and cries easily, and somewhat explosively, which inclines one to think of pseudo-bulbar symptoms. The knee-jerks remain very exaggerated, and there is still most generally cerebral congestion, and cyanosis of the extremities. We may still think, therefore, of precocious dementia, and fear its advent despite the quasi-cure won by force of care.

During the period of this state, if one may say so, there had been, moreover, a marked tendency to "catatonic" suggestibility and negativism. The suggestibility persists. In this particular case we did not find any element of original predisposition, whereas in the published observations that element seemed somewhat distinct. Here there appears to have been no emotion: the patient has never even remembered the shock. On the other hand, I have observed several patients in whom the puerility has been more transitory and roughly sketched, restricted to the voice and language for several days, as also to sudden fears and defensive attitudes, the arm raised before the face like a child who expects to be beaten. Slowly but surely

these patients have progressed towards dementia præcox, which is really, after all, the clinical group with which these curious manifestations should most legitimately be connected. But it is too soon to say if these cases are absolutely incurable. As we shall see further on, in the prognosis of shell-shock one should be extremely cautious.

D. *False General Paralysis.*—Mairet and Piéron, and then myself, have pointed out at the Academy of Medicine that the shell-shocked may present the appearance of general paralytics, although the subsequent history of the case enables us to correct the diagnosis. Confirmation of this fact will be found in a very interesting article by Pitres and Marchand (*Revue Neurologique*, Nov., Dec., 1916) on those symptoms of shock which simulate organic disease of the central nervous system.

Concerning general paralysis, a preliminary remark is necessary: there are shell-shocked patients who become general paralytics, remaining as such until death, and in whom the malady appears to have been latent up till the time of the shock. We treat here not of these, but of those who have recovered, or whose symptoms have subsided. The observations made are sometimes very impressive; so much so, that if I had not had a certain number of cases myself, and if the recovery had not already lasted, in some cases for several months, I should apprehend an error of diagnosis. Sometimes, as was the case with a patient of Pitres and Marchand's, there has been a period of dreamy mental confusion after the shock, sometimes also polymorphous delusions, which throw light on the diagnosis; but in other cases from the beginning there is only extreme confusion with amnesic stupor, which strongly resembles depressive general paralysis. Moreover, the *physical signs* are still more puzzling: exaggeration of the knee-jerks, tremor of the tongue and of the fingers, pupillary reactions slow or excessive, and in some cases pupillary inequality, fibrillar tremor of the facial muscles, which are hypotonic, and this gives a very characteristic expression of inertia to the

countenance. Speech is slow, syllabic, pronounced with difficulty in a monotonous voice; and even, particularly in the case of three patients in whom the sequel completely excluded general paralysis, there were impediments of speech absolutely identical with those of true general paralysis. It is impossible to lay too much stress on the clearness of these symptoms and on the ease with which we may be mistaken about them. *Diagnosis may be impossible, temporarily at least.* It may be a needless reminder to say that the cerebro-spinal fluid, with its lymphocytosis and slight albuminosis, increases the uncertainty. As to the reaction of Wassermann, that does not clear up the difficulty: there are too many paralytics with a negative reaction, and too many syphilitics without general paralysis, for it to have any other value than that of an indication. In reality the best argument against general paralysis, and in favour of a complication of shell-shock, is the *intensity of the motor phenomena*, relatively to those of the mental disorders. The jerks and muscular tremors of the face, in particular, would correspond to a very advanced general paralysis, but examination shows that there is more confusion than dementia: a somewhat subtle distinction perhaps, but one which has its value. With our patients, the period during which the paralytic symptoms were dominant has varied from a few weeks to close on a year. With them all, the mental state was the first to clear up, well before the motor symptoms. One of them had for months a noticeable difficulty of speech, and a marked pupillary inequality.

E. *False Organic Cerebro-spinal Lesions: Pseudo-Meningitis.*—The same article by Pitres and Marchand describes some abnormal confusional symptoms, which I have come across myself, though less clearly perhaps.

Insular Sclerosis, which, in ordinary clinics, is, in the main, usually a symptom of disseminated lesions, is easily enough simulated by these shell-shocked conditions: exaggeration of the reflexes, tremors and hesitating speech—all as I have already pointed out. But the

permanent element of mental confusion and of cerebral congestion, inseparable from cerebral shock, generally points to the diagnosis.

Meningitic symptoms present a more difficult problem. In fact, it is principally a problem of the constitution, and of bacteriology. When a shell-shocked patient complains of very acute headache, holds himself like the hammer of a gun, has intense photophobia and a Kernig's sign, we may be sure that at the least he has increased pressure of the cerebro-spinal fluid, doubtless actually hemorrhagic. He certainly in that case has an attack of meningitis. The diagnosis is important only from the point of view of treatment. When we have become acquainted with the commemoratives we may better appreciate the facts and avoid an intra-spinal injection; which would at best be useless.

Emotional Types

We will leave aside the excessive and tenacious emotivity of certain patients, of which we have already spoken, and take into account only the more complex syndromes.

A. *Persistent Secondary States and Convulsive Fits.*— It is possible that these several phenomena are not all of the same nature; however, they often occur together, and all generally follow on a period, sometimes a lengthy one, of mental confusion. They usually make their appearance in already predisposed cases, and the emotional element is all the more probable since we may sometimes, though not often, observe the same clinical conditions without shock, but under the influence of strong emotions.

However that may be, a considerable number of shell-shocked cases have for a varying, sometimes an indefinite time, *fits*, which are either a state of automatism—a secondary state—which comes on and goes off quickly, or a convulsive fit of variable form. We may witness every stage, from the simple faint,

up to the severe hystero-epileptic fit with extreme opisthotonos, and even up to the classic epileptic fit with biting of the tongue and involuntary micturition. It is clear that disparate cases are grouped together here. The trouble is that it is sometimes very difficult to say if such and such a fit is of a neuropathic or alcoholic nature, or even of a comitial nature. It is not even possible to draw any conclusion from the time at which the first fit made its appearance, or from the fact that the individual, not having lost consciousness at the time of the shock, is likely to be chiefly an emotional case, and the symptoms hysterical. There are on record excellent observations, among others one by A. Léri, in which fits of a jacksonian character have appeared some hours after the shock, in a patient who had not lost consciousness. It is probable, however, that these epileptic fits are much less frequent than are fits of a solely neuropathic kind. Good management in the hospitals, the use of a psycho-therapeutical treatment made effective by real discipline, has very much reduced the number of patients who have fits, and this has decided the ordinary nature of the latter. Some, however, although they are evidently hysterical, are excessively obstinate, and at the same time serious owing to their intensity. Concerning these, the question of simulation comes in. We shall return to this later on.

B. *Dumbness and Deafness.*—Dumbness and deafness also rank with neuropathic symptoms, by their character and the persistence with which emotion and drink play the principal part; and they are among the most readily maintained by persistence. They have been studied by Roussy and Lhermitte in their volume of that series devoted to the *Psycho-neuroses of War*, and if mention is made of them here, it is because they are among the most frequent of the emotional complications following on shock. Also because, except for cases caused by shock, they are not frequent. This observation may perhaps signify that emotion does not play an exclusive part in the

matter, and that, at least at the outset, it may be in some degree concentrated on some physical disorder, perhaps, very unimportant, but still a real one. What has been said already about the symptoms of labyrinthic shock supports this hypothesis. Deafness, in any case, appears to have an organic origin more frequently than dumbness has, and the former is less influenced by circumstances and by therapeutical methods which have a psychical action. Deafness is sometimes added to mental confusion, which it may perhaps help to maintain. As to dumbness, it is most generally associated with secondary states and with convulsive fits. It is not uncommon for speech to return in the course of a fit. There is, therefore, an important difference between the deaf confusional patient who speaks and the dumb one, whether the latter be deaf or not. The first is scarcely ever suggestible, while the dumb one must be subjected to psycho-therapeutical methods as early as possible. In the early hours, or even in the first few days, of this accidental complication, psycho-therapy, aided by faradization, is nearly always successful. Once the infirmity is established, it is very obstinate. Surgical anæsthesia by ether, by chloride of ethyl, or by chloroform also gives good results. So does hypnotic sleep sometimes (C. S. Myers), but this should only be used with a certain caution.

Tremors, Jerkings, and Vicious Attitudes.—There is a series of motor manifestations also which belongs to the emotional syndrome following on shock, and of which a detailed account may be found in the volume by Roussy and Lhermitte. In themselves they have not any mental significance, and it is but rarely that they are associated with any marked mental disorders. These may occur, however, and I have seen either post-shell-shock tremors, or, once at least, a bending attitude—camptocormia—linked with a very distinct condition of mental confusion. For the rest, we know that these post-shock tremors are far from being entirely of an alcoholic nature. As with muscular atrophy, so

with these, some have, in all probability, an anatomical substratum, more particularly the unilateral tremors, and those which take the form of the parkinsonian syndrome.

These tremors, as Henry Meige has clearly shown, are influenced in certain patients by an obsessive preoccupation with the tremors—*tremophobia*. This mental complication should be kept in mind here. Some cases raise considerable difficulties of construction, such as those of Laignel-Lavastine and Courbon (*Annales Médico-psychol.*, 1916, p. 498) relative to a shell-shocked case with stereotypic gait, attitude, and expression, and a professional auditory hallucination. The patient, a year after the shock, continually heard in his ears the electric bell for which he used to listen in the days when he was messenger at an hotel.

Circulatory Types

Certain of the shell-shocked recover fairly quickly from their mental symptoms, only a little mental fatigue remaining, besides their exceptional sensibility to disturbances and noises. They have no neuropathic manifestations, no disorders of sensation, no secondary conditions. But they have, for months after the shock, a peculiar state of the circulation, to which it is necessary to call attention; on the one hand, because its real cause is usually unknown; on the other hand, because of the share it has in the general make-up of the syndrome of shell-shock. This condition may be expressed in one word—*hypotonia*.

The pressure, low in all the shell-shocked, is still lower in these; the veins look dilated, the circulation is sluggish, the extremities are cold. The least exertion causes breathlessness, and generally a cardiac gallop, which indicates an insufficient cardiac contraction relative to the mass of blood to be propelled. Frequently there is tachycardia, but unlike the Basedow tachycardia, this is not permanent; and it differs from emotional tachycardia in that it is not influenced

by psychical conditions as much as by physical effort, even when slight.

The test of cardiac resistance, after the method of Lian, shows that these patients no longer have any circulatory resistance. That is all they suffer from, but as their disorders are not well known, and, moreover, do not present any valvular cardiac lesion, they are generally looked on as mere neuropaths, and it is for that reason that by a lucky chance they are sent off to a neuro-psychiatric centre. Often enough they only get there after a series of unsuccessful efforts to get them back to work. I have seen some who had been discharged from the army solely because the weight of the knapsack when marching brought on evident cardiac failure and syncope, but who, once discharged into the auxiliary services, exhibit some affection quite as trying as that they had during their regimental service.

Besides these men, of whom it may almost be said that they have both heart and vessels strained, there are patients suffering from exophthalmic goitre, in whom circulatory symptoms less distinct than in the preceding cases are accompanied by swelling of the thyroid, tremor, and ocular phenomena. Chavigny, du Roselle and Oberthür, Laignel-Lavastine, Lortat, Jacob and others have observed them. I have seen two cases, not very pronounced, but distinct. The reader may be surprised to find these cases mentioned here and not in the section devoted to emotional states, but Graves's Disease, even when it appears to have had an emotional origin, is distinguished from the pathological emotional states by the intervention of internal secretions, and the vago-sympathetic system. Now, it is precisely that system that we shall find at work in the pathogeny of shell-shock.

§ 4. Pathogeny

We have just reviewed a series of important clinical cases, many even presenting serious symptoms of a more or less lengthy duration. However could they have been produced without any external wound?

At first an obvious answer was given. Taking into consideration the circumstances in which these symptoms supervened, it was said that they are caused by emotion, in the cases under consideration by fear. And the populace, which does not bother itself to look for the causes of these diseases *sine materia*, has stuck to that explanation. "Such and such a one," say they, "has been frightened by a shell." The soldiers, themselves, who have seen the most courageous reduced to a state of human rags and tatters by shell-shock, fall rather into the reverse error, and are inclined to attribute to shock all the sudden psychical and neurological phenomena which come on unexpectedly during a bombardment. Most assuredly it is natural to allot a considerable influence to emotion in all this, and it would not be in the least surprising if, acting with such intensity and such suddenness, it were solely responsible. Indeed, that is just what some have upheld. In other countries the symptoms of shell-shock have been spoken of as neuroses of fear. In France, Ballet and Rogues de Fursac have argued as follows: All that is observed in the shell-shocked can be produced by the emotions; there is, therefore, no need to separate the syndrome of shell-shock from the syndrome of emotion—it is all only emotion.

And Roussy, who, in his successive commands, has obtained most excellent results among the hysterical—even among those hysterical shell-shocked cases in which there are neuropathic manifestations—thinks that the share of the organic element has been very much exaggerated, and that in the great majority of cases the symptoms are solely emotional. Except for a few details, this is the impression given by the studies of Georges Dumas spoken of before, and to which it will always be necessary to return for the study of mental confusion of emotional origin. But these authors, not being able to exclude certain cases with ascertained lesions, more common, however, among the shell-shocked with neurological symptoms than among those with psychical symptoms, can only

attribute a preponderating share to emotion, not an exclusive one. Let us see if the emotional theory satisfies the mind sufficiently to allow of ascribing to it all that is demanded for it. There are both clinical and etiological arguments to judge it by.

From the *clinical* point of view, is it correct to say with Ballet and Rogues de Fursac that *all* the complications of shell-shock can be reproduced by emotion? Emotion, especially if sudden, startles, arrests, paralyses, oppresses, inhibits—*Vox faucibus hæsit.* That we agree to, and accordingly we have noted that deafness is essentially a neuropathic phenomenon. As for paralysis, which, however, is far from being common among the shell-shocked, we know that it often takes the form of hysterical paralysis; and we are not surprised at the success of Georges Dumas, who relieved it in the earliest days as easily as if it were dumbness.

But these modifications of muscular tone, which make some patients appear to be general paralytics; this vascular hypotonia with tachycardia from exertion and not from emotion; this pupillary inequality—even these trophic disorders, such as zona or an acromegalic syndrome, which was very distinct in the case of one of my patients—these disorders, which have such a definite organic signification, are they possible consequences of emotion? Search among the worst horrors for some influence comparable to that of shell-shock. I have in my department a man of whom I have spoken in connection with mental confusion, and who fell into the state of confusional stupor on the delivery of the sentence which condemned him to death. He has nothing of a shell-shocked case about him.

Above all, there are records such as those of maritime catastrophes, that of Hesnard before the war, who very carefully studied the mental condition of a certain number of patients at the time of the catastrophe to the *Liberty*. There is that, still quite recent, of the late lamented Clunet, who having once escaped death at the time of the torpedoing of the *Provence*, described, with a dramatic simplicity, the nervous injuries that he

had observed and cured. These symptoms only supervened when once the patients were in safety—as with those emotional cases which I distinguished from shell-shock—and they consisted in an absolute immobility, with contraction of the four limbs in a state of flexion, dumbness, and constant grinning. All these symptoms were short-lived. The patients, when warmed and thoroughly well massaged, all returned to their normal condition. What a difference between these patients in a state of extreme contracture and quickly cured, and the shell-shocked patients, inert as a puppet of which the strings are broken, whose reflexes are all exaggerated, and who remain in this condition without possibility of speedy relief! Thus there is no *identity* between the effects of a mortally intense emotion, both sudden and lasting, such as that which occurs among the passengers of a torpedoed ship, and the symptoms presented by the shell-shocked of war.

Can *etiology* give us any better indications? Every shell that bursts does not produce shell-shock cases. What are these pathogenic shocks, and also who are their victims?

It is the explosion of shells of moderate calibre, or else perhaps of mines, which are most efficacious in causing shell-shock. The lower calibres take less effect, and as for the big ones, they leave no survivors within the radius of their explosion. This leads to a remark in passing. The partisans of the purely emotional theory say: How does it happen that one never sees a wounded shell-shocked case, and that there is a sort of incompatibility between a real wound and the accidents from shell-shock? It is because, *when there is, at the same blow, a serious wound and shell-shock phenomenon, the wounded man dies in a state of shock.* And when there is a slight wound, we shall see further on that it may of itself serve to reduce the internal effects of the explosion.

Then what counts is not merely the intensity of the explosion. It seems certain that in the open country the casualties are less serious than in the trenches.

Why? Because, the sides of the trench, being so close together, reverberate the waves of pressure and augment their effects. The worst shocks occur in a closed place, in a dugout or casemate.

From the individual point of view it has been said, and Maurice Dide has decisively demonstrated it with regard to a battalion of riflemen, that the number of shell-shock casualties depends on the moral of the men, on the influence of their leaders and their physicians. This is quite true, but even so, it is advisable to come to an understanding. So far as the consequences are concerned, yes; so far as the casualties which are purely emotional from the first moment are concerned, yes; but not as concern those shell-shocked who are in a condition of shock. A high moral energy, such as is maintained in these picked troops, drives away the symptoms of fear and hastens the recovery of slight cases. But there are cases which it can neither suppress nor influence. And if these cases are less numerous among such troops, that may be due to other circumstances. My colleagues, notably Grandclaude, have specially noted the influence of overfatigue; above all, of the long and heavily laden march through the communication ways a short time before the shock; the effect of a less wholesome diet taken at irregular hours—influences which are debilitating generally, and especially to the circulation, and which are probably less common in those corps in which it is customary to keep the well-being of the men up to as high a level as the circumstances permit. Besides, there are men who are not sent into rifle battalions, which demand a superior physical fitness, but who are quite in their place in an infantry regiment. Now it seems evident that the weakly are more severely affected than the strong. Among these weakly ones it is necessary to note down all those whose circulatory system is not sound, those whose vascular tension is habitually below normal. Those who have been shell-shocked before should also be specially mentioned.

In short, there is no doubt that an habitually weak

moral aggravates, maintains, and complicates the casualties from shell-shock. But the most constant and steadily high moral does not bring security from these casualties. It is thus necessary to find another cause for them. It was thought to have been found in direct *contusion*: the patient having been thrown over and up by the air-wave, his body ends by striking the ground with a force which some have deemed sufficient to cause these casualties. H. Claude, especially, has published some interesting facts as to this. But if one stops to think of it, these cases can only be the exceptions, considering how rare it is to find contused wounds on the shell-shocked. Besides, that reason would only be valid with regard to the head. When endeavours were made to produce experimental shocks of the spine in animals we learnt that it was necessary to use considerable force if the effects were to last longer than a few minutes. Certain facts decisively contradict this theory, such as the case of that former pupil of Alfort's, accustomed to physiological investigation, which Babinski reported in June, 1915, to the Neurological Society. He had been smitten with paraplegia and hæmorrhage into the cord when lying on the ground, and without having been blown up or displaced by the explosion.

Shell-Shock; the Circulatory Apparatus; the Nervous System.—The circumstances under which shell-shock makes its appearance, as well as the results of autopsies, called for attempts at a mechanical explanation taking into account the internal lesions which were discovered. For this reason comparisons have been made between the casualties from shell-shock and those from rapid atmospheric decompression—"caisson disease." The analogy is legitimate. In both cases there are sudden modifications of pressure outside the individual, sudden symptoms specially affecting the nervous system. We know, as a matter of fact, that if those who work in compressed air are not subjected to a slow and careful decompression, accidents happen, the mechanism of which is nowadays well understood.

But there was a preliminary difficulty in assimilating these two classes of phenomena. In an explosion, the obvious element is the expansion of gas and air from a centre, the existence of centrifugal waves, of a violence and suddenness which surpass all imagination. It is a case of over-pressure. Now it is not easy to see how theories relative to decompressions can be applied to these of over-pressure.

The response to this contradiction has been furnished, apparently, by several arguments of a physical kind. They invoked—Sollier and Chartier did so with reserve—the rarefaction of the air in the interior of the cone of the explosion, having as a consequence an inward suction travelling from the surrounding regions of air, and consequently a diminution of pressure. The existence of this returning air-wave is proved by numerous phenomena—this, among others: when a shell explodes in a street, the broken glass is generally strewed in the roadway, and not in the rooms. Attempts have been made to measure, or at least to estimate, the force of this decompression. Numerous experiments have been made, which took as their starting-point facts ascertained by M. Arnoux with regard to an aneroid barometer. This, which was rendered useless by the explosion of a shell, fell to 350 millimetres. In two articles in the *Annals of Public Hygiene*, Chavigny gave a detailed account of the data he employed in his researches, which were carried on with remarkable strictness, and which definitely proved that the supposed decompression has no influence. Never does the centripetal wave produce effects comparable to those of the centrifugal wave. The instance of the windows is a peculiar one. In it there are intervening conditions of elasticity and vibration which are not found in the human body.

There is, besides, a common-sense consideration which may be invoked here. What provokes the disorders in decompression is that, on the one hand, during the period of over-pressure, gases have been dissolved in the blood in excess, according to the operation of

Dalton's law; and that, on the other hand, once the decompression has taken place, it is permanent. Only one part of the phenomenon is instantaneous, but what is essential is, that there should have been a *preliminary* phase of storage of gas in the blood, and that thereafter these gases should have every chance of disengaging themselves, the decompression being lasting. This is so much so with divers that the longer the compression lasts the more serious the symptoms are, because a greater quantity of gas has been dissolved in the blood. And so if we recompress directly after the decompression, we reduce the morbid symptoms.

For, as Paul Bert has shown, caisson disease is essentially due to the disengaging of the gas bubbles from the blood and other fluids of the organism. Now this disengagement is not instantaneous, any more than was the previous solution of gas in the blood. If, as I did in 1899, we submit animals to a rapid decompression of ten atmospheres, we may see the liberation of the bubbles by means of an immediate autopsy.

In shell-shock through an explosion, there is no disengagement of gas, because there was no preliminary slow compression and accumulation of gas in the blood. The return to the normal following on the compression caused by the explosion is not accompanied by a disengagement of gas, because the period of compression was too short. And if it were demonstrated that there is, at that moment, decompression in comparison to the normal, it would still be without any effect, because it would not have lasted long enough.

Per contra, in shell-shock there is a colossal pressure, at least within a short radius, the effects of which are known by experts by the special name "wave resistance" (Vielle), as Sollier and Chartier have reminded us. How this pressure can lead to lesions is what remains to be determined. All the same, and contrary to all expectation, it is to the results of rapid decompression that we must turn for an explanation. As a matter of fact, these do not consist solely of Paul

Bert's phenomenon, the disengagement of gases from the blood. In 1900 I exhibited to the Biological Society accessory lesions, of no importance as regards caisson disease, but which here become essential.

When the spinal cord of rabbits that have been subjected to a rapid decompression is examined, it is found that, besides the lesions due to the disengaging of gas bubbles in the central canal and parenchyma, there is a quite peculiar disposition of the vessels. These are dilated and *increased in length*, for instead of being rectilinear they are sinuous, or even distorted into spirals. These lesions can be perfectly seen in portions of spinal cord set directly after the experiment, and may still be seen after several days' survival. Thus they are lasting. Sometimes there are little ruptures in the distended vessels, and hemorrhages. Why is there this distension? It is caused partly by the disengaging of the gases, which take up some room in the interior of the vessels, but principally by the extensive congestion of the vascular territories with blood driven from the abdomen. The gaseous distension of the bowel is enormous, and because of this, all the blood of the abdominal vascular plexus, which represents a considerable quantity, is driven into the neighbouring regions. Bouchard had duly considered this phenomenon, to which he attributed some pathological importance in caisson disease.

To return to our shell-shocked patients. We have seen that many of them complain of having received, as it were, a blow from a fist in the abdomen. That is because, of the whole body, the soft part most easily affected by outside pressure is the abdomen. At the moment of the explosion, that part gives, the blood which it contains is driven out, not as in the case of decompression by the disengagement of gas from the intestines, but simply because of the pressure from without. This blood, forced into the entire circulatory system as if by a piston-stroke, expends its pressure in the general and cutaneous capillaries, since the time during which the pressure was exerted was very short.

But the organs contained in an inextensible cavity, and in a state of pressure equilibrium, such as the central nervous system, suspended as it were between the blood pressure and the cerebro-spinal fluid, bear the whole brunt of this excess of pressure. In this way the central nervous system inevitably receives a vascular blow from a battering-ram, exactly analogous to that which constitutes the accessory lesions of caisson disease.

Those organs richly supplied with blood vessels, the lungs, the liver, and the bladder, are likewise the seat of congestive accidents of the same kind at the moment of the shock. This is proved by hemorrhages, slight, but unmistakable, in the cerebro-spinal fluid, and by the quasi-constant simple hypertension of that fluid, as also by the venous dilatations in the fundus of the eye when examined with the ophthalmoscope. And what proves incontestably that all this is essentially vascular is that, besides the proof of hemorrhages afforded by autopsies, there are cases, such as that of Georges Guillain, in which a hematoma of the cord occurred *a month after* the shock, thus proving the permanence of the vascular lesions. But there are thousands of men who have remained unscathed in the near neighbourhood of an explosion; there are also thousands of shell-shocked in whom the cerebro-spinal fluid is not hemorrhagic and who have apparently had no vascular rupture.

It is at this point that the theory needs completion. It is easy to understand why, at the moment of the impact of the pressure, the vessels should become distended; at first sight it is less easy to understand why this distension should persist.

Now, it persists not only in the spinal cord of decompressed rabbits, but also in the circulatory system of the shell-shocked, since we have noticed that, in those cases in which the symptoms are lasting, hypotension is found.

This is because, by the intermediate agency of the vessels, the battering ram acted on the nervous system,

but much less on the central nervous system than on that of the vessels themselves. The immediate consequence of the explosion is a vaso-motor paralysis of the suddenly distended vessels. The consequences of this vaso-motor paralysis are much more marked on the brain than on the spinal cord, by reason of the extreme vascularization of the meninges, the pia mater, and the central nuclei. And that is why the consequences of shell-shock are much more generally cerebral than spinal.

Anatomically, vaso-motor paralysis is productive of œdema. Now, œdema has been discovered by Leriche in the course of trephining. This œdema is not only a cause of discomfort in the closed cavity of the skull, it has the effect of impeding the cerebral circulation, from whence follow impaired psychical action, and headache. According to the way in which the cerebral circulation is disturbed, divers clinical symptoms may supervene : cerebral torpor with confusion, stupor, or on the contrary excitement, which may be psychic or motor, and which ends, according to the case, in dreamy states or in a convulsive fit.

This vaso-motor disturbing action is not a hypothesis, nor a novelty. It is now just twenty years ago that the existence of cerebral vaso-motor nerves was established, almost simultaneously by Morison and by Obersteiner, and that, owing to this discovery, Courtney, of Boston, suggested the part played by cerebral œdema and vaso-paralytic anæmia in the disturbances from direct shock.

In 1899 I published with Boyer a fatal case of shock from blows on the head, without any fracture, and which in autopsy had disclosed œdematous congestion, without lesion of the nerve substance.

It is not simply in support of this theory that what happens in a case of concussion from direct shock may be mentioned here. There is a real and evident analogy between the after-complications of the shell-shocked and those of the trephined. Now with these last, as we shall see, it is much less the loss of cerebral

substance—there is often none—which matters than the intensity and the permanence of the congestive phenomena round about. And this analogy holds good not only as regards such permanent symptoms as mental confusion, vertigo, cephalalgia, and an exaggerated susceptibility to sensorial impressions. It also exists in the transitory symptoms, particularly with respect to convulsive fits, which may be due in both cases to simple variations of cerebral vaso-motor action.

Thus, all the circumstances calculated to increase the circulatory stasis directly after the shock should, if the theory is correct, aggravate the concussional symptoms. Likewise, all those which would tend to re-establish the circulation should mitigate the symptoms. In fact, there is nothing worse for a shell-shocked case than to be buried, to have the thorax caught under a fall of earth or rubble, which produces asphyxia. Inversely, there is truth in the current statement that those of the shell-shocked who were also slightly wounded, and especially if they lost blood, have moderate concussional symptoms ; the loss of blood affecting the vascular equilibrium so as to contribute to the return of a normal circulation. In the same way, good results ensue from immediate treatment with energetic vascular tonics.

However, in such a matter no theory can claim to explain everything. This one has physiological arguments on its side, probable for a certain number of cases perhaps, but many other conditions may and should be considered. Time has made us lose sight of Duret's old theory of cerebral disturbance through the dashing of the fluid on the floor of the fourth ventricle. There may also be in some patients a bulbar localization which must be taken into account. It was through shock that an exceptionally rare case of bulbar hemorrhage was caused, which was reported by A. Léri.

According to several observations, which have the disadvantage of being anterior to the epoch during which the modifications of the circulatory equilibrium

have been studied in the shell-shocked, a direct shock from a blow on the skull may produce cellular lesions; and, indeed, there may be some truth in this. However, it must be remembered that, taken altogether, these symptoms from shell-shock are curable, which is more reconcilable with lasting circulatory disorders than with actual cortical lesions.

There may be other nervous lesions besides cortical lesions. It is possible that the initial shock and excessive pressure in the circulatory system has reverberations in the ganglia and the plexus of the sympathetic abdominal system.

When one sees certain shell-shock cases, stupefied, without reaction, in a state of total inhibition, one cannot help thinking of Goltz's frogs, and also of the well-known share of the sympathetic system in all the phenomena of collapse. If one admits that at this time minute but lasting lesions may be produced, it helps us to understand the later symptoms, especially those in which extreme hypotension predominates.

The sympathetic system, the vago-sympathetic rather, should not be considered apart. Already Loeper has very carefully described, notably with respect to the supra-renal apparatus, the glandular reverberations from shock. Space is lacking here to touch on the very useful information which may be gained from these researches, which are still in progress; but already it may be seen that we must not exclude what physical changes there may be, and take into account solely the emotional, either as regards the general shock to the nervous system or the labyrinthine shock. It is possible that the discovery of new data may soon determine the physical mechanism. Nothing excludes, in fact, the reasonable hypothesis of Sollier and Chartier that the composition of the explosives may be an intervening factor sometimes, especially with patients in a state of coma, who are defenceless against the inhalation of toxic gases. Are we to conclude from what precedes that emotion has no share in the causation? It assuredly has one.

But it is not everything; and perhaps, apart from the emotions of the first moment, it most often tends to the fixation of the disorders, as a secondary influence grafted on an irritant thorn of an organic nature.

It is because of this that it is sometimes difficult to distinguish the syndrome of shell-shock from the emotional symptoms which nearly always complicate it.

The distinction drawn by Mairet and Piéron, and by Clovis Vincent, is a useful aid, but in practice it would lend itself to criticism if it were adhered to too absolutely. At all events, they had the merit of affirming that certain post-shock manifestations could only be explained as the result of emotion.

Above all, it would seem that this result is extraordinarily effective when it follows slowly and secondarily to the shock, on to a ground already prepared by the latter. I have pointed out already the exaggerated emotivity of the shell-shocked. I have several times seen the state of some patients very much aggravated after an emotion.

One of the most distinct was that of a confused shell-shocked patient, whose case had been well observed at the hospital to which he had been sent, and who had only moderate depressive confusion, with a slight tendency to stupor, without dreaminess or delusional reaction or agitation. But as a convalescent, his condition remained stationary, and when the time came for him to return to the front, his family, finding him too confused, had him examined at home with a view to prolongation of leave. He was then looked on as a malingerer. They told him this, and spoke of a court-martial. He at once fell into a much greater state of confusion, with fits of anxious madness, which made it necessary to send him to a centre of psychiatry, and which proved somewhat lasting.

Hence we see the difficulty of diagnosis, especially of pathogenic diagnosis. However, from the preceding considerations we should bear in mind that in seriously shell-shocked cases caution is always necessary.

§ 5. Prognosis and Treatment

From the prognostic point of view there are several issues.

On the whole, the majority of the shell-shocked from the field of battle should recover very quickly without being evacuated beyond the base, but not till after a sufficiency of rest in some quiet spot, sheltered from noise and disturbances. It is unnecessary to speak of the simple emotional cases.

Among those of the shell-shocked evacuated because of serious symptoms, the majority also should recover in a few weeks. But there remains a large minority of patients whose symptoms are tenacious, and for whom the prognosis should be extremely cautious. Even with those who may be held to have made a rapid recovery, we must take into account the extreme susceptibility to noise and all emotional and sensorial impressions, and be prudent as to their employment.

Among those who take a long time to recover, and who remain for months, either in a confusional state or suffering from serious circulatory disorders, it is possible that some may never recover their health. With them it is very probable that the accidental complications induced minute lesions of the brain, those cicatrices apparently so unimportant, and yet, as Pierret has pointed out, of such great pathogenic importance. However, considering that, as a rule, we are dealing with youthful patients with a healthy circulatory system, the general prognosis for the shell-shocked should be: extremely cautious and even pessimistic as regards duration, but relatively favourable as to eventual complete recovery.

The treatment should, if possible, be pathogenic. In default of sufficient indication in that respect, one should bear in mind certain empirical rules: to combat energetically the circulatory collapse at the onset, to apply warmth if there be necessity for it, and as soon as possible. To evacuate beyond the zone of fire, and to a specialized department when the

intensity of the symptoms demands it. There, the maximum of quiet. The shell-shocked should be cared for like those injured by a fracture of the skull, for from the organic point of view there is no essential difference between the two cases. It is possible that a little ice on the head may be useful sometimes, especially where there is excitement. Plenty to drink, diuretics, cardio-vascular tonics, will be more useful. We may try adrenalin, but with prudence, because of the possible effects on the vago-sympathetic system.

Those who have fits should be isolated, and one should combat the manifestations of chronic alcoholism by a prompt and efficacious psycho-therapy, generally aided by electricity. We should combat the slightest tendency to alcoholism. As for the prolonged sequelæ, whenever it is possible, agricultural work should be resorted to. It is the most certain means of bringing about the complete disappearance of the fits of those who have them only rarely, and, above all, it is an excellent means of ameliorating the cerebral circulation. A trephined case is less amenable to it, because the changes of position make his brain press on his cicatrix, or, on the contrary, drag at it, according to his position. But the shell-shocked, whose skull is intact, may stoop. Exercise in the open air, without haste, is invaluable for him.

As conclusions to this special chapter on the pathology of war we cannot do better than re-read those of Pitres and Marchand in their article on the syndromes of shell shock.

First of all, one cannot be too carefully on one's guard against those errors of diagnosis and prognosis which might eventually lead to the disregard of the organic pathology of the shell-shocked.

Secondly, clinical surgeons would be very much mistaken if, under the pretext that the provocative traumatism was not accompanied by any external wound, they were to persist in seeing only purely functional disorders of emotional origin, either hysterical

or pilhiatic, in post-shell-shock phenomena. The cases we have just described, although they had not received any visible wound, were evidently neither failures nor shammers. Without any doubt they were actually wounded, internally wounded.

V.—CEREBRAL EXCITEMENT AND MANIA

Modern psychiatrical classifications do not all admit the existence of mania, if by mania is understood a separate psychosis consisting of cerebral excitement, with motor agitation, but without delusions or confusion. Because of the frequent recurrence of attacks of mania and their eventual alternation with melancholia, a new theory has arisen, that of *maniacal depressive psychosis*. In this conception, the attacks of mania and of melancholia, either consecutive, or sometimes, it may be, combined in a blending of symptoms, are only the different expressions of a permanent and fundamental disorder. This question need not be discussed here, nor need we show that the old definitions of French alienists are more in accord with modern clinical observation than foreign pathological notions are; but from the special standpoint of war psychiatry one remark is needed.

The surgeon who looks on those of his patients who are depressed as being affected by maniacal depressive insanity runs a great risk of being mistaken. We have seen how serious, how weighty, are the causes of depression directly engendered by the war. They lead to the conclusion that predisposition, which in the theory of maniacal depressive insanity is the chief concern, is here only a secondary one.

The same is true of mania. At the front it is certainly not only an inescapable manifestation with relapses, or, if one prefers to put it so, with eclipses. But it is quite possible that the old *mania* of authors was not a disease at all. That would mean that in the main it was only a common enough symptom of

cerebral excitation, brought on in predisposed cases both by over-fatigue, and doubtless more especially by emotion. It is a reaction of an unstable nervous system, also perhaps of a not very well developed nervous system. And it is in order to reach this conclusion that I have had to treat the problem on theoretical grounds. It must, indeed, be well understood that if an attack of mania occurs, we must find out if there may not have been a cause for it. Often enough it will be found to be *alcohol.* Most assuredly a fit of mania must not be confounded with delirium tremens, which is accompanied by an element of mental confusion that is lacking in a maniac; but the maniac is not infrequently an habitual drinker in moderate quantities, as one may drink at the front, and yet be considered sober; but one day the permanent excitement increases after some over-fatigue, an attack of influenza, or an incident of war, into an attack of mania. To tell the truth, to judge from the somewhat large number of maniacs who have been sent to the Lyons Centre, there is hardly ever anything more than a submaniacal state; that is, a cerebral excitement incompatible with service, a source of troubles and disorders, and sometimes of danger, but not the wild, intense maniacal paroxysm which may be seen in lunatic asylums. In the army, maniacs are generally taken in hand in time.

They are easy enough to recognize: they are incorrigible chatterboxes, who cannot be checked. The presence of a superior officer of high rank does not overawe them; quite the contrary, for it provides them with another auditor, one to whom they delight to talk.

Also, their movements are restless, their initiative overflowing, their zeal is indefatigable, generally disorderly, but it may make an illusive show. They are never tired. They do not sleep. They act and talk incessantly. In proportion as the crisis approaches the excitement increases, any relative repose lessens more and more, and accordingly the activity becomes

more incoherent, and the speech more rapid and incomprehensible. At this stage the patient becomes irritable, and frequently menacing. He is extremely dangerous in the neighbourhood of the enemy, through the unexpectedness and utter imprudence of his acts; he should be evacuated without a moment's delay. But, again, as a rule his case has been seen to in time.

I have compared an attack of mania with mental confusion, and from the clinical point of view it is certainly to be distinguished from this, but we must not place too much reliance on symptoms. The two may not be incompatible. It must be borne in mind that there are maniacs whose paroxysms occur when their hearts or their kidneys have some transitory weakness; and in such cases it is difficult to say whether there may not be some toxic infection. It must be added that such subjects are always hereditary degenerates. But that is a common characteristic with many maniacs. In a publication which dates from a little before the war, Séglas, with that clinical insight that is so remarkable in all his work, adverted to the maniacal paroxysms of the debilitated. He pointed out the fewness of their manifestations, which assimilates them to those affected by dementia præcox.

Therefore it is necessary, whenever there is time to do so, to examine thoroughly each of these maniacs, and to bear in mind the responsibility of the decision that must be made, to consider carefully the causes of the paroxysm, and to decide in the same way as we should if the mental disorder were an attack of mental confusion. We know that the disorder is transient; it is the mental stamina and external circumstances, which are of importance. Very often the mental debility of these maniacs betrays itself in their exalted ideas. One of the best cases of this which I have come across was that of a sergeant of military hospital orderlies, a former hospital porter at the A.P. of Paris. "I operated with Poirier," he would say. One fine day the casualty clearing station at which he happened to be was bombarded by aviators.

Our man bestirs himself, gives the orders, for several hours expends an unexpected energy in transporting the wounded into the cellars, arrogates to himself absolute authority, and does so much in such a way that it ended in his being himself evacuated, after having been warmly congratulated to begin with—perhaps in all good faith, but I would sooner believe that it was in the hope of calming him.

On his arrival at the hospital there was the same familiar exuberance, the same hand held out to all comers, the same useless initiative. And, moreover, there were somewhat imperious requests that I should write to the superior officer of the Army Health Service from whence he came that Sergeant X., having as much medical knowledge as of military initiative, should be promoted to be an aide-major of the second class. At this I again examined the sergeant's pupils and tried his reflexes. This megalomania had an unpleasant appearance of general paralysis about it. But it was not that, as the event has shown. The fact is, that a maniacal condition of this kind most certainly does show itself at the beginning of general paralysis, and often all the physical signs combined are none too many to enable us to make a diagnosis.

In some epileptics there are dangerous paroxysms of excitement, which resemble those of mania. They are distinguishable from them by their sudden onset, and their much greater frenzy.

Besides the maniacs from the front, at each collection of the men on sick leave, the psychiatric centres of the base receive cases in which despair at being recalled to the front has caused an attack of mania. It is easy enough to form an opinion concerning them and to procure any necessary information. But as maniacs can generally reason correctly, and as the excitement of the brain sometimes gives an acute enough turn to their minds, it is likely that they will be regarded as malingerers or undisciplined buffoons. We do not include here those whose stay in hospital began in disciplinary quarters.

The maniac should receive treatment; with all due deference to those who believe in the existence of a maniacal depressive insanity, and who suppose that no treatment has ever been able to prevent or shorten an attack. The correct therapeutical treatment is the prolonged bath, to which should be added purgatives, and calming anodynes (bromides, valerian). Energetic sedatives, such as hyoscine, that "chemical straight-waistcoat," should not be used except when it is necessary to control great excitement, or when the patient must make a journey.

VI.—ACUTE ENCEPHALITIS AND INFECTIOUS MENINGO-ENCEPHALITIS

The facts grouped together in this section are very disparate, but owing to the usual difficulties of immediate diagnosis, there are some advantages in treating of them together.

§ 1. Infectious Meningo-Encephalitis

Acute encephalitis, characterized by headache, torpor, a confusional state, and some fickle and variable disorders of the general motor activity, is a very rare, but possible, complication of certain infections. Generally the phenomena are much less pronounced, and are confined to a delusional confusion which may be fairly quickly cured, and such is the usual history of all these infective insanities. A little care will suffice for the avoidance of mistakes, and the previous and concomitant existence of some serious infection decides the diagnosis. The question is more difficult when, instead of being anatomically limited to a congestion of the cerebral cortex with cellular reactions, the lesions tend towards purulent inflammation and an abscess.

In war pathology, an abscess in the brain is usually associated with cerebral traumatic lesions and with the presence of intra-cerebral foreign matter. This

will be considered later on. But it may arise from other causes, of which by far the chief is aural inflammation. This redoubtable complication, with which aurists are well acquainted, but of which doctors do not always think, comes on in the course of an ordinary chronic otitis to which the patients have long become accustomed. The cerebral complications of acute otitis are inflammation of the sinus and of the meninges; chronic otitis, which generally only reaches the brain through the slow erosion of the roof of the tympanic cavity, begins in a quiet microbial colonization of the temporo-sphenoidal lobe or the cerebellum. A vague headache is the first sign of it, then one fine day the symptoms burst forth; an inexplicable general uneasiness, a noticeable slackening of the pulse, torpor with depression, and a tendency to stupor; very rarely there is a little delirium, and in a few days the patient falls into coma.

A diagnosis may be made through the knowledge of the old established otitis, the spontaneous and provoked *pain* on one side of the head, the photophobia, the *pupillary inequality*, and sometimes that paramount symptom on which Lannois and Jaboulay have so rightly laid stress, *hemianopsia*, which is a sign that the abscess is far back in the temporal lobe, and which is a valuable indication in favour of operation. Indeed, the practical interest attached to these abscesses of the brain, whatever may be their origin—and more particularly to abscesses of aural origin—is that cure is possible by surgical intervention; although if left alone the patient would certainly die.

In those infectious abscesses whose origin is not in the ear, local symptoms may be altogether absent, and the general symptoms themselves, especially the fever, of small intensity. The clinical picture may be solely that of a mental state.

§ 2. Acute Encephalitis of Unknown Origin

I observed in 1915, and at the beginning of 1916, some ten cases, closely similar, which I described in

some articles on the neuro-psychiatric centres published in the *Revue Neurologique* under the title of "Arteritis and Encephalitis of Fatigue." The sole purpose of this publication was to draw the attention of doctors to cases of this kind, so that they might make allowance for the part taken in their production by the war, and especially by over-fatigue. What predominated was an extreme adynamia, which the patients themselves attributed to recent overwork. They were nearly all territorials, about forty years of age. But there was more the matter with them than weariness and overwork. Brought into a state of cerebral torpor, they had every one of them paretic symptoms in addition to begin with, and paralytic symptoms followed, which in some cases were *hemiplegic*, while in others they were *paraplegic* or *quadriplegic*. These phenomena went on increasing, each day the intellectual obscuration grew more intense, alimentation more ineffective, and wasting more pronounced, until death supervened. Unfortunately, a lumbar puncture was made in only two of these cases; it showed an average lymphocytosis in a clear fluid, with perhaps rather more albumen than is normal.

In several cases typhoid and para-typhoid agglutination was tried, and was always negative. There was no fever, except for 38° every now and then towards the end. Absolutely flaccid paresis and paralysis, with the reflexes diminished or absent. No photophobia, or Kernig's sign. No meningitic symptoms. Heart feeble and irregular. Signs of premature general and arterial senility. Two were formerly fibrous tubercular cases. No digestive symptoms.

In default of any better explanation, I attributed these cases to abnormal changes from progressive hemiplegia and softening of the brain in men who were overworked, in a toxic condition, and whose circulatory system had been seriously damaged beforehand. I intended to search for a more complete explanation if any new cases presented themselves,

but since the beginning of 1916 I have not come across another.

On the other hand, it seems to me that there is some analogy between them and such observations as the following: Dumolard, Rebierre, and Quellien published at the Société de Neurologie and in the *Paris Médical* some singular remarks on the variation of the reflexes in certain asthenic conditions of exhaustion, generally without alteration of the cerebro-spinal fluid, but sometimes with it, and with, in some cases, progress towards dementia.

On November 11, 1916, Pierre Marie and Ch. Chatelin brought before the Société de Neurologie three observations under the following title: "Note on a syndrome of more or less generalized flaccid paralysis, with abolition of the reflexes, heavy albuminosis, and yellow coloration of cerebro-spinal fluid, with spontaneous progress towards recovery, and of an indeterminate nature."

Guillain, Barré, and Strohl had already published closely similar cases before the Medical Society of the Paris hospitals.

Before the same Society, on April 27, 1917, R. Cruchet, Moutier, and Calmette reported forty cases, collected in nine months in a psychiatrical army-centre, under the title of "Sub-acute Encephalo-Myelitis." They especially singled out a *mental* form, "in which the cerebral torpor, amnesia, bewilderment, pupillary disorders, tremors, pains in the joints, also the paraphasia and the reactions of the cerebro-spinal fluid point either to general paralysis, or to another variety of dementia." They, moreover, pointed out other forms, *convulsive*, *choreic*, *meningitic*, *hemiplegic*, *pons-cerebellar*, *bulbar*, *acute ataxic*, *anterior poliomyelitic*. There were only two deaths caused by the disease, both bulbar; but recovery was usually excessively slow. The possible connection between these different observations is evident. It seems to me that they should also be connected with cases observed in German and Italian armies, and described as neurasthenic

polyneuritis. The extremely asthenic condition, which struck all the French writers, may very well be the result of a somewhat special Korsakoff's syndrome. The mental symptom that I have noticed was exactly the torpor of the polyneuritic psychosis, in the stage of ingravescence, and before the subsidence of the disease has disclosed that remaining amnesia, which is so specific, and which has long since been described. This polyneuritic psychosis—if this it is—and the quadriplegic tendency which has been observed in all, suggest a toxic *neuro-cerebritis*, to use Pierret's term, which was employed by Haury also in his thesis. It may even be permissible for us to surmise that the disease may be an infection. All my patients came from the army at a time in which the army administrative centres had not yet reached their present stage of development. But is it really a specific infection? It is very improbable, and I doubt it. In any case, here is, in all likelihood, if not a new army disease, at the very least a mental syndrome which should not be ignored at the risk of depriving its victims of the notification "contracted at the front," which in such cases seems to me to be only their due.

§ 3. Various Acute Infections

Meningo-Encephalitis.

The description already given of mental confusion renders it unnecessary to lay stress here on the different forms of acute meningo-encephalitis, which are possible complications in every infectious disease. There should be no difficulty in recognizing and treating confusional delirium in the case of an infected wounded man, or in the course of a pneumonia, influenza, or eruptive fever, in which both the special symptoms and the general phenomena would attract attention.

What is necessary is to be cautious, to auscultate and thoroughly examine every raving patient, and to take his temperature. In this way we may avoid subjecting a case of pneumonia to a long and trying

journey, sometimes with methods of control which belong to another age. It is well understood that in all these infective cases, the raving and the mental confusion arise from the general infection; and that the expectation is that they will recover from the one along with the other. But there are more difficult cases.

1. *Acute Meningo-Encephalitis of Aural Origin.*—We have seen that chronic otitis generally gives rise to encephalitis with an abscess of chronic progress. As a rule the complications of acute otitis are, on the contrary, of a tumultuous character. But it is not always so, and I once received into my centre, with directions for immediate internment as a case of dementia præcox, a man who was in a condition of mental confusion consecutive to a recent attack of acute otitis. Here, again, it was advisable to consult a surgeon and to consider an operation.

Epidemic Cerebro-Spinal Meningitis.—There may be no mental disorder in a case of epidemic cerebro-spinal meningitis; generally, however, a slight degree of mental confusion forms part of the clinical picture. This confusion is worse during the night. Sometimes there is more. There may be violent, even furious ravings, having all the appearance of an attack of acute mania. Or the confusion may be so great as to mask the meningitic symptoms. During the last two years some ten patients have arrived at the Lyons psychiatrical centre, all coming from the dépôts or sanitoria of the town, and consequently provided with regular medical attention and means of rapid investigation, which were, after all, only cases of cerebro-spinal meningitis. In each case the mistake was entirely excusable.

It is also necessary to recognize those states of depression and confusional ravings with a persecutional tendency, which sometimes mark the decline of cerebro-spinal meningitis, and which may exceptionally constitute lasting sequelæ. Formerly they passed as being both common and serious, and during the illness we

generally expected to find that after it there would be a diminution of cerebral activity. Similarly, every one knew of the disastrous reputation of typhoid fever with regard to the brain. Nowadays, balneotherapy has very much ameliorated the mental prognosis in typhoid fever, and it also much improves that of cerebro-spinal meningitis. This is due, no doubt, to serotherapy, and the better organization of the war against infection. However, attention to details is of great importance, especially during convalescence. The British Sanitary Services, which are very well organized in this respect, show much more favourable results as regards mental sequelæ than those we have been accustomed to. Prolonged rest in the open air seems to be particularly efficacious. These precautions are necessary, and there may perhaps be reasons for attaching special importance to them. The allied armies will be reinforced by contingents of a remarkable physical development, but which, judging from the consensus of American publications on the subject, are particularly susceptible to infectious poliomyelitis and epidemic cerebro-spinal meningitis.

3. *Typhoid and Para-typhoid Meningo-Encephalitis.*—Reactions following on vaccination. Slight mental confusion forms a usual feature in the clinical picture of typhoid fever, as also of the para-typhoid affections. It is exceptional for the mental phenomena to become predominant, since the treatment is now much more successful in counteracting the infectious element. When there are mental symptoms, they usually take the form of confused stupor, much more often than that of excited raving, and they chiefly affect predisposed cases, as may be seen especially in some interesting observations by P. Merklen. It should be noticed that para-typhoid, like typhoid fever, may cause cerebral arteritis (Legroux). But the danger of typhoid fever to the mind is less during the acute stage than from the remote consequences of the disease. There are two possibilities.

(*a*) The mental disorders which come on during the

illness may not subside. The patient passes insensibly from dothien-enteritis to sub-acute and chronic mental confusion. He has been, as it were, burnt out. This is quite exceptional.

(*b*) Recovery has been good; only there is a little intellectual torpor left, and some loss of memory. It is not pronounced, and has to be looked for to be discovered. Then, several weeks or months afterwards, some circumstance arises in which the patient is called upon for the exercise of intelligence, initiative, or will-power, and he fails. Suddenly, a considerable intellectual deficiency is revealed. An investigation is made, and it is found that since he had typhoid fever he has never been quite the same as he was before. It is chiefly from the medico-legal standpoint that these cases are important. We must not be in a hurry to believe that typhoid fever, whatever its bacteriological variety may be, has been completely cured because the patient after his return from convalescent leave has been able to return to the front.

Anti-typhoid vaccination has in some cases, which were exceptional in the number of injections made, given rise to nervous complications, even to some of a neurotic type. They most often seem to over-excite the convulsive tendency of those patients who have occasional fits. They have been followed by attacks of mania or melancholia in periodical cases (Mairet), and by sundry variable psycho-neurosal symptoms. It would seem that, on the whole, these disorders are somewhat obstinate.

4. *Exotic Epidemic Infections and Diseases.*—In certain recent epidemics *exanthematic typhus* appears to have been marked by forms of delirium of a meningitic character, as well as by the usual confusional element.

Dysenteries operate like all infections during the acute phase, but they rarely have any psychical sequelæ of any importance, though they sometimes leave behind a depressive condition connected with innutrition.

On the other hand, ague is an important cause of

mental confusion, which may accompany the attacks, and sometimes complicate the interpretation of delirium grafted on neurotic lesions. In any case, we know that sufferers from ague may have attacks of mental confusion of malarial origin long after having left the malarial district. There is no need to point out, except as a reminder, the attacks of delirium in pernicious ague, but Hesnard has drawn attention to those prolonged malarial psychoses that are only mental confusions maintained by the combination of anæmia, the bad general condition, and the recurrence of paludism. Among the natives of Algeria in Porot's practice, *recurrent fever* occurred with acute and violent ravings, and with impulsive escapes, which were more impressive than the psychical troubles. A sudden access in a native of acute delirium of which alcohol was not the cause, should lead one to think of recurrent fever.

5. *Tuberculosis.*—A word is needed as a reminder that meningeal tuberculosis in an adult often enough declares itself by an attack of raving or confusion. Sometimes it takes the form of classic acute mania, sometimes that of a strange torpor, without any raving, and which is established in two or three days. Without warming, the patient falls into a state of semi-coma, with incessant restlessness, but without any real excitement, and revealing by some indistinct complaints the pain in the head from which he suffers. Death sometimes supervenes before the classic symptoms of meningitis have had time to manifest themselves.

6. *Syphilis.*—We are concerned here not with the chronic and later symptoms of cerebral syphilis, or of para-syphilis, but with those cases, rare, but not unknown, in which the meningitic invasion of the secondary period has assumed the form of an encephalitic syndrome. They are cases it is necessary to be acquainted with, especially because it seems probable that they leave some consequences in the predisposed. Upon the whole, it seems certain that the fatigues and

emotions of war render these premature infections of the central nervous system more frequent.

7. *The Revival of Encephalitis.*—The term revival, which we owe to Pierret, suits those cases in which the morbid process arises from some old lesion, which to all appearance had long been cured. I have seen two patients in particular, who had both been attacked in their childhood by infantile encephalitis, which in one of the cases had left the patient with a club-foot, which had been operated on. In this last case there appeared, following apparently on some slight infection, a short attack of confusion, after which epileptic fits occurred. In the other case there was simply an attack of confusion which came on without any other cause than that of fatigue. It seems that alcoholism played no part in either of these cases.

VII.—ACUTE MENTAL DISORDERS AND ALCOHOL

It may create surprise not to find in an account of acute mental diseases any chapter devoted to emotional psychosis or to alcoholic psychosis. A double answer is easy : neither emotion nor alcohol has the monopoly of any form of mental disorder; and, on the other hand, they have their share in nearly all cases of the acute mental disorders of war.

Emotion.—This entered the soul of the bravest from the first day. And it has never left him, not even though one gets accustomed to everything, and though habit not only acts as a support, but also supplies a certain way of thinking. Emotion is never spoken of, but it is always there. And very often, when the moral armour has been laid aside during the short long-hoped-for leave, emotion becomes master for the time. How many men returning to the front after leave of absence, and taken into custody at the station, incapable of continuing their journey, have I not already received into my clinic!

Most assuredly with many of them the interruption

to their journey has been caused by alcohol, but certainly not with all of them; and among those who did get drunk, how many of them did so to get rid of emotion, to forget it? When it is emotion, *i. e.* fear, which unsettles the brain, we have seen its effect is to produce ordinary hallucinatory confusion, which differs from other cases of confusion, and especially the confusion of infections and alcoholic intoxicants, only in degree.

Is there, then, no means of recognizing the share that alcohol takes in a case of mental disease? Visual hallucinations, together with a certain angry excitability, or perhaps sudden ideas of vindictive persecution, with impulsions, a distinct increase of the symptoms during the night, congestive flushes of the face, a watery eye, and a bristling moustache—all these make one think of alcohol. But it is so often present without one suspecting it! And it has done so much to plunge patients into that second state which is one of the varieties of mental confusion, and which delivers its subject over to every automatic impulse! It has so often contributed to the slow deterioration of the soldiers in the trenches, instead of being for them simply an exceptional viaticum, thanks to which the machine-guns of the enemy remain unheard as they set out for the assault! It has corroded so many stomachs, compromised so many digestions, peopled with dreams of blood the scanty sleep snatched from perpetual anxiety! It has reduced will-power, substituting reflex action for it. It has diminished the elasticity of the circulatory system, so that when the battering blow from shell-shock is received, it finds the blood vessels inelastic, rigid, prone to stasis, congestion, and œdema. In its victims it has prolonged for an indefinite time symptoms which in other cases are soon over, even as, by diminishing the vitality of the organic tissues, it delays the healing of wounds. I have spoken of those cases of unexpected encephalitis which several of us have observed, and for which we suspect some unknown pathogenic agent. But the

clinic tells us that some resemble arteritis, and others Korsakoff's polyneuritis. So that the thought of alcohol, of sly and noxious alcohol, is again forced on the attention. I have pointed out that cerebral excitement, or hypomania, is common in troops both on active service and resting, whenever they are able to drink as much as they wish. They have drunk much, they still drink much. Those behind the lines have never drunk so much before; and when we consider the alcoholism of the war-working woman, and that of her neglected children, never has alcoholism appeared so menacing for the future. But at the front also they drink a great deal. When the camp followers are driven away—if they are—they return again in their legions owing to the natural cupidity of the populace; and even at the extreme front, if there are absolutely sober sectors, there are others in which false hygienic ideas have left alcoholism without a check, through the blind indifference of those in command.

A third of the cases in my practice were due solely to alcohol—more than half, two-thirds perhaps, if we count those who were prepared by alcohol. Statistics such as those of Charon at Dury, and those of the Val-de-Grace, give the same impression, almost the same numbers. And if instead of numbering the cases one weighs them, according to the old precept, what a terrible indictment there is against the poisoners! How many of these disorders, but for alcohol, might have been nothing more than a slight nervous ailment, and in an abstemious subject are no more than that! It is clearly evident that mankind has an unlimited capacity of adaptation, and unknown resources of endurance and energy. Among us he has shown *ad infinitum* examples of heroism, most simple and most natural because they were so disinterested and so unalloyed. But that makes us all the more angry when we think of all the lives that have been lost: here because an over-alcoholized unit has not shown at the critical moment the coolness it should have done; there, because alcohol, which acts not only on the

nervous system, has contributed to the wasting of the effectives—anger against those who are responsible for peril, and even now, to-day, are fighting it only by half measures, and as it were reluctantly.

"Ah! Monsieur le Major," said one of the earliest of my patients to me, "it is twenty years ago that the Government ought to have forbidden absinthe."

Never will it be possible to say what alcohol has cost us, never shall we sufficiently realize the deplorable results of that toxic, artificial state of mind that is set up by it, and of which these acute psychoses are only one of the varieties.

"From the point of view of degradation and madness," says André Gilles, "the alcohol consumed in peace-time has done more harm to our men, and more to unsettle their minds, than all the tragic horrors of the war."

CHAPTER II

CHRONIC MENTAL DISEASES

The interest of chronic mental diseases is very different from that of the acute disorders. In the first place, the majority of such cases date from before the war, and the problem of causation and of the responsibility of the State, so difficult in the acute diseases, can here be solved without much trouble. Then there is much less hope from treatment, which sometimes even proves to be fruitless, so that the conditions of admission and stay in a hospital, and of discharge, are of less importance.

Some of these chronic diseases are, however, of real importance from the military standpoint, all the more so because they do not always command attention, and many of them raise much more complex problems of legal medicine and of destination than the acute cases do.

I.—CHRONIC MENTAL CONFUSION

We may not at the outset grasp the difference between chronic mental confusion and the dementias, which will be considered later. In fact, the difference is infinitesimal in the case of the primary dementia of youthful subjects. It is much more distinct between chronic mental confusion, properly so called, and the paralytic, arterial, or vesanic dementias.

Chronic mental confusion is a state of organic disease. It is the indefinitely prolonged sequel of an acute attack. Dementia is more entirely mental. The following examples will prove this.

§ 1. Infections, Toxic and Emotional: Chronic Mental Confusion

In the type, this is an acute confusion which has not been cured, as, for instance, a typhoid fever patient,

who has never recovered his mental integrity, and who remains confused and amnesic, inert and stupid. I purposely choose typhoid fever as an example. There must be some serious infection, or else a strong predisposition, to allow of mental confusion becoming chronic.

Or it may be a man worn out, wounded, and anæmic, who has endured continuous sufferings and privations; and such is the case with many of our men who are repatriated from Germany as insane. On reading the accounts, often very complete, which accompany them, we receive an impression that moral burdens weigh heavily under such circumstances, and that home-sickness, separation, and anxiety have much to do with it. But predisposition must certainly be added to them. These men were specially lacking in power of endurance, and when there has been no momentous incident of the war to diminish their power of resistance in a considerable and legitimate way, we are bound to admit that they must have always, or at the least for a long time, had "invalid" brains.

This instability may have been acquired. Many among them are former alcoholics. Moreover, it is possible through alcohol alone to reach a special state of besottedness, kept up by the bad organic action of the digestive canal, the liver, and the kidneys, and which is nothing but a state of chronic mental confusion. Territorials employed behind the lines, or, more rarely in the combatant troops, have kept up and perfected old habits of intemperance. A day comes on which their cerebral deficiency becomes manifest, and they are sent back. We then find before us men old before their time, twenty years older than their certificate of birth would indicate, and incapable henceforth, and perhaps for ever, of taking care of themselves, and of earning their own living. Hence arises that double problem of assistance and invaliding, to which we shall return in another chapter. The clinical diagnosis does not present any great difficulty except with respect to general paralysis and the organic and vesanic dementias. Here we may recall the general

indication given by Chaslin, and by all those who have closely studied mental confusion. Cases of confusion, even the chronic cases, are really ill. They both look so and have the orthodox symptoms in liver, kidneys, alimentary canal, and circulation. Cases of dementia, on the contrary, look like perfectly healthy people. As a consequence, even in the chronic conditions, treat as if for acute confusion, by rest in bed, disintoxication, and quiet. Chronic confusion may be cured even after it has lasted for months. In cases of emotional origin, the prognosis remains good for a very long time. It is the same with certain confusions following on wounds, with prolonged infection and a general bad condition.

§ 2. Chronic Mental Confusion following Shell-shock

The same general considerations hold good. Doubtless this also figures among the returns from Germany; but information is inevitably lacking as to the origin of the symptoms. When we have witnessed a shell-shocked man fall into a state of chronic mental confusion, we should not lose hope too soon. Besides, it is exceptional for the confusional sequelæ to take the form of a persistent *serious* state of confusion. What is more often seen is a state of torpor and suffering, with slight cerebral congestion, which renders the patient useless, at any rate temporarily, for military duty, but which does not in the least call for an indefinite stay in hospital. These protracted cases are, therefore, from the army point of view, cases that specially call for discharge.

§ 3. Primary Chronic Mental Confusion: Premature Dementia

Although the dementia of youthful subjects, *premature dementia* is a real "dementia"—that is to say, a general and definitive impairment of the intellectual faculties—it is legitimate to mention it here, because, in fact, it so often manifests itself by symptoms that

are analogous to, if not identical with, chronic mental confusion.

Cases of premature dementia have been numerous in the services of the interior, either at the time of mobilization, when the experience of the first few days at the dépôt has shown that they were unsuitable to take the field, or at each call up of a class, and at each recall. Even when their outward appearance does attract attention, this may be due only to transient reasons of a physical kind, or again it may be exaggerated or simulated; and it is only natural that the medical authorities of the military appeal tribunals should not have the time and the experience necessary to examine these patients thoroughly and detain them on the way.

It is especially regrettable that, through the working of the system of re-examination which the Dalbiez Law organized for the invaliding of soldiers, we are almost sure to see cases of premature dementia called up again, as the commissioners do not seem to be sufficiently informed of the reasons for the first rejection. This problem, common to many mental cases, often arises in cases of premature dementia of young men, who belong to the classes which normally should furnish a large contingent to the army. It arises especially because premature dementia is an essentially deceptive disease, which, even in its serious forms, is subject to remissions, which may very legitimately lead to error.

Two cases in particular, may present themselves in confirmed primary dementia. The first, that of primary dementia with stupor and catatonia, is hardly ever seen in the army. It would scarcely be possible for it to be so, unless there had been just then a decided remission, under cover of which the patient had been incorporated in the army and sent to the front. The clinical picture of this form is well known. There are extreme emotional insensibility, motor inertia, relative cyanosis of the extremities, the turn of mind may be persistently distorted, or more rarely illogical, with

silence, and negativism. We can only surmise whether there are insane ideas of a melancholic nature, and whether there may not be some active mental process.

The question also arises, whether there may not be simulation, but that question is not a difficult one for any one who has had some experience of psychiatry. Inertia and apathy may be simulated, but it is not possible to simulate the whole of this peculiar and complex condition. These patients should be transferred to a hospital, where observation determines the diagnosis.

The second variety is more troublesome: it corresponds with primary dementia, sometimes with a less advanced stage of the disease, and in any case may lead to more prolonged errors. In this variety there are simply lacunæ of the critical sense and sudden incoherent unsystematic insane ideas. The outward appearance of the patient is normal. Bonhomme and Nordman described some who had been in asylums before, and in whom important remissions had led to their retention in the army. Haury, who has done much to draw attention to this class of dangerous persons, has published an account of an advanced case of primary dementia in a volunteer. This was before the war, but he has had many others since the war began. A dépôt at Lyons, which receives a large number of conscripts, has several times sent me men who seemed to be odd during their course of military training, and who were nothing but unrecognized cases of primary dementia. What are the signs which may lead one to suspect this disease? To begin with, there are repeated and inexplicable military crimes. A man will remain in bed in the morning after reveille, declaring that he has the right to lie as long as he chooses to. There is another who is systematically late, or who, despite severe punishments, persists in wearing an untidy uniform. Often it is a man who isolates himself from his comrades, and one fine day refuses to eat, betraying ideas of having been poisoned, although up to then he had shown no signs of melancholia. In

addition to these delinquencies and unreasonable actions, there are curious moments of *absent-mindedness*, during which it is evident that the patient does not hear what is said to him; and there are also, what is the most important of all perhaps, *sudden and explosive fits of laughter*, coming on unexpectedly for no reason, and after which the patient just remains silent and absorbed. At the same time there is a total emotional insensibility. If the man is at the front, he will completely forget to write to his parents, who become anxious about him. After this opening period, some incident or the other follows, which suddenly reveals insane ideas. It may be running away; or the man may seek out one of his officers and aggressively reproach him with having come to insult him the night before; another may be haunted by the idea of animals running over his body, and which he cannot—for a very good reason—succeed in catching. These outbreaks are often sudden, and utterly incoherent and absurd. Often they do not last—one idea supersedes another.

For this, no treatment is of any avail. The patient must be discharged as promptly as possible. These madmen are among the most dangerous from the first onset.

II.—MENTAL DEBILITY

The subjects of primary dementia have been intelligent, some even very intelligent. Those of mental debility, on the contrary, have a constitutional status which has not changed. They are as they have always been. Only, for the most part no one had noticed how incapable they were, because they were doing easy work, always the same, with nothing unexpected or calling for initiative in it. There are all degrees of mental debility, but an excellent way of recognizing it is always to compare what the patient can do in an occupation of which he has learnt the routine, with what he does on his own initiative, or in an occupation

which is new to him. In his suggestive book on *Abnormal and Mental Patients in the Regiment*, Haury clearly shows that it is the feeble-minded men of the regiment who are always late, incapable of getting themselves out of a difficulty, slow and embarrassed, unable to understand anything that has to be acquired, and *a fortiori* anything which requires an intellectual effort. One such man will never learn the rules for firing, another will always fail in some movement at drill, and another will never remember the formalities, however elementary, of barrack life.

In peace-time what happened was usually this: the weak-minded man got himself first warned, then punished. From the moment that discipline exercised its authority over him, fear came to paralyse what poor faculties remained to him; and according as the opinion of the officers or of doctors prevailed, it ended in his being called before a court-martial or invalided out of the service.

Since the war, we have had to be less exacting. Some doctors, heads of regimental hospitals, thoroughly conscious of their duty and at the same time solicitous of public interest, have systematically eliminated all advanced feeble-minded cases, either at the dépôt or on their arrival at the front. But even so, too many of them have been retained at the front. The feeble-minded man is certainly as emotional as he is stupid. The poverty of his intellectual faculties, and more especially of his will, delivers him over defenceless to all his own impulses, to which he freely gives rein. No respect for public opinion will serve to restrain his panic, and if to that we add that he is credulous and suggestible in the highest degree, and that in his unit he is doomed to be the dupe of every practical joker, we may easily imagine what his life in the army may be, and the consequences that may result from his presence there. In any case it would be impossible to find a worse sentinel.

Where the doctor is not particularly cautious, or when the commander wishes at all costs to utilize every

single man, there is delay till the revealing incident occurs. Delay takes place all the more easily since, taken all together, there are a great many feeble-minded, and as life at the front is sometimes very simple and monotonous, and the feeble-minded person is generally well-meaning and docile, he takes people in. Then one day, when there is no choice of men, some mission or some difficult task is confided to the feeble-minded one. He does it so badly that a penalty becomes necessary; and this leads to his discharge or to his being sent before a court-martial. Very often the commandant's report accuses the man of unwillingness or of an inexplicable failure. The non-commissioned officers say that up to then he had never given cause for any remark. It was known that he was not very bright, but from that to do what he has done—— Inquiry of the police shows that he worked regularly before the war, consequently he can have no mental disorder. If the inquiry be carefully made, it will be found that he had an infinitesimal salary, and that his job was of the simplest. If his schoolmasters be questioned, it will be discovered that he never remembered anything; and, finally, from his parents may be gathered certain characteristic details, such as the fact that he used to wet his bed up to the time of his adolescence.

Or it may be the manifestation of some insane idea that puts an end to the military career of the feeble-minded man. One fine day he calls upon his captain, or his major, and gives him advice. He feels he is capable of commanding, and sometimes he even believes he is going to receive distinctions or be raised from the ranks. It is not uncommon to observe a foolish *megalomania* of this kind, without any settled delusion, in a feeble-minded man, for the brain is too barren to be able to form a delusion. I had in my hospital a man who knew quite well that he was still a second-class soldier, and yet who, without any hallucination, and without any obvious delusional construction, had been for some time thoroughly persuaded that he would be called to

some high command. At first it was impossible to find out on what this conviction rested; but, finally, we learnt that before the war he had been employed as a supernumerary in the theatre of his little provincial town, and that he had sometimes impersonated nobles and warriors. At more than thirty years of age, this would-be General exhaled a most pronounced odour of urine, owing to his persistent incontinence. Finally, it may happen that without there having been any call for action beyond the capacity of the patient, he may commit some crime, generally that of running away. The starting-point may have been some stupid mistake, or else the feeble-minded man's credulity.

So far I have only spoken of the quiet and gentle feeble-minded. There are perverse and mischievous feeble-minded cases, whose peculiarity is chiefly owing to the difficulty they have in restraining their instincts. They become medico-legal cases. We shall also see further on that though it is absolutely necessary to keep decidedly feeble-minded men away from the firing line, still, many among them, and certainly those who are only slightly feeble-minded, can be used in certain auxiliary forces behind the lines.

III.—CHRONIC PERSECUTORY DELUSIONS

It will not be necessary to dwell much on the chronic persecutory delusions, the nature of which is evident as soon as the delusion becomes fixed, and the diagnosis of which is, on the other hand, very difficult during the premonitory period, and necessitates an authoritative opinion. But during this first period, what we have to deal with is principally a state of depression; the hallucinations and delusions do not come till later on.

In fact, the chronic delusional cases we see the most of in the armies, or in the centres at the rear, belong to the following categories.

Degenerates with polymorphous delusions, generally mystic or prophetic in character. These are often enough

seen in intelligent but unstable persons, who are very impressionable, or who have been strongly suggestionized by an emotion or a succession of emotions. Men and officers who have been taken prisoners have had delusional reactions of this kind.

Cases of mental debility, with fits of confusion, which are very destitute of imagination and detail, and have a basis of megalomania. The reformers of the war, the inventors, the people who send in memorials, belong, according to their education and intellectual grade, to one or the other of these two varieties. I do not doubt that the ministerial department that is consecrated to inventions concerning national defence has in its archives numerous examples of each of them.

Cases of persecution, originally only slightly degenerate, but *alcoholized*, and perhaps also influenced by events, with more or less systematized delusions, commonly enough under the form of jealous imaginations.

Primary dementia, with incoherent delusions and brutal reactions.

Persecutory delusion through insane fabrications, with its variant, revindicational delusions, often grafted on a wound or illness.

All the preceding forms, as well as others which seem to be less common, are chronic. Therefore, when the delusion is indubitable, there is nothing to be done but to send the patient to some centre where a decision may be made with regard to him. It will be remarked that many of these delusions, even when chronic, are recent ones, for if they had been old ones, they would have led to their victims being put into lunatic asylums while they were still civilians, or, at the very least, to a treatment which would doubtless have prevented the patient being called up to army service. However, the following points must be taken into account: the calling up again of invalided men has brought into the army many persecutory cases, whose habitually calm condition had allowed of their living at liberty.

The persecutory patient does not consider himself to be ill, and so does not complain of his pathological

condition before the military appeal tribunals, or the courts of discharge or incorporation.

The fact that there are persecutory ideas does not necessarily mean chronic delusion, as has long been believed to be the case. We made mention further back of these acute persecutory delusions, originating in a state of depression and anxiety.

Nearly all chronic persecutory cases have an important basis of mental weakness, especially those who have ideas of grandeur. Megalomania is the result of a primary mental debility, or of an acquired weakness. The persecutory cases of the war are, as a rule, either meekly anxious, or arrogant feeble-minded cases.

IV.—GENERAL PARALYSIS

General paralysis is more common in the army than one would imagine, and it is all the more necessary to have attention drawn to it, since its manifestations frequently assume a criminal character in its opening stage (medico-legal stage of general paralysis).

The war, among other psychiatrical acquisitions, will have established the fact that in many cases general paralysis has begun a very long time before the first day on which it has been noticed. The numerous investigations which have had to be made, in order to determine the origin of a demented condition with a view to invaliding the patient, bring to light, from time to time, among much negative information, indications of extensive disorder. This reflection is necessary, for it explains why the beginning of the war disclosed an appreciable number of general paralytics undiscovered till then. It also explains the very distinct accelerative influence of the circumstances of the war, and thereby justifies a liberal conception of what is due to general paralytics and their families in all that concerns invaliding and pensions.

The Apparent Onset.—The majority of paralytics do not notice their decadence at any time, but there is a minority which does discern it for at least a few short

moments, and this is always at the initial stage. Consequently there are a few general paralytics who present themselves for examination. It is true that their complaints are chiefly of feeling out of sorts, of fatigue, sleeplessness, dyspepsia, sometimes of headache. Only a few patients, accustomed in the conduct of their business to reflection, or obliged to exert themselves intellectually in the course of their military duties, specify that they feel unequal to that exertion, that they wear themselves out to no effect, or become aware of curious forgetfulnesses, or mistakes. In war, inattention is not permissible, and in such cases the duty of the physician is to prescribe rest and observation. At this time there is often no physical sign that points to a diagnosis. There is as yet no absolute difference between certain cases of mere fatigue and some cases of general paralysis. Generally, however, we discover that the intellectual fatigue complained of by the patient has not been caused by any real overwork; that it is disproportionate to the effort made; that the patient is more impressionable, more irritable; and if we have already known him for some time, it is not uncommon to detect that there is some change in his physiognomy. These are delicate, sometimes fleeting changes, which some days of rest will serve to dissipate for the time, but which can hardly be mistaken by any experienced medical man.

These same changes are met with again when it is not the patient himself who has come to the doctor. They are in that case more distinct, because the disease is more advanced, the incident has attracted the attention of his comrades. At this time the form the disorder may take is very various. Sometimes, especially in the case of an officer, it is the intellectual impairment that is specially noticeable, and surprising lapses of memory. The same order may be given several times in the day, or contradictory orders, or there may be forgetfulness of one of the regular and daily acts of military life, or yet again a sudden incapacity for coming to a decision, a sort of annihilation of the will.

Very often there are alterations of character, such as an impulsive irritability, or simply a sort of unreasonable suspiciousness in a person of a normally open and expansive nature. More rarely there is cerebral excitement with its consequences, excessive activity, insomnia, a delusional tendency, with euphoria, high spirits, and self-satisfaction. These cases are generally very rapid ones, and are hardly ever seen except following on special circumstances of physical and moral exhaustion, which have suddenly used up the patient's power of resistance. These cases of excitement may be seen at the war, after episodes of drunkenness also. We know that these episodes in themselves are to some extent pathological, and an expression of cerebral excitement. Again, in some cases, the excitement takes effect on the sexual functions.

It is to this cerebral excitement, already involving dementia, that we must ascribe *eccentricities*, the unexpected and motiveless actions by which in the main the paralytic reveals himself. It may be some detail of deportment or equipment, or some stupid trick played on a comrade and repeated with a strange obstinacy. One man took to drawing all the nails out of his shoes. It was noticed, and he was scolded and punished. He did it again several times in succession. What also strikes us is that these general paralytics are no longer young. They are usually about forty, and their eccentricities and rude jests are neither consistent with their age, nor, as a rule, with their former character.

It is not uncommon for the eccentricity to be directly linked with the cerebral excitement, and instead of being an insignificant but unreasonable action, to be already such as to bear witness to the state of the brain. A gendarme, who had been back from the front for some time, and who up to then had given no cause for unfavourable comment, goes on circuit with the court of appeal. The neighbourhood of the authorities, the good, well-moistened repasts, bring on excitement. In the intervals of the sittings he takes to haranguing the

populace, gives the village women advice as to the care of children, and holds forth on the subject of depopulation. A remonstrance only serves to increase the scandal. He is sent to me as an urgent case. It is found that he is married and has children, but has completely forgotten it. We investigated his life and the way in which he had fulfilled his duties in the army, and up to the last few days there had been nothing abnormal; yet there is no doubt that in his case the disease was already pretty well advanced.

Delinquencies.—It is easy to understand that under these conditions the disease is quite likely to reveal itself by some distinctly criminal act. We see this in civil life, in which the opportunities for committing offences are very much less numerous than in military life, and in which there is much more chance of their passing unperceived.

The principal infractions of paralytics are *running away* and *theft.* Both will be treated of in the chapter on legal medicine. It need only be remarked here that all these crimes have a character in common—their unskilfulness. They bear the stamp of dementia. There are some cases in which, without going as far as to commit an actual crime which indicates cerebral automatism and lack of control by the mind and the will, the patient manifests an exaggeration of his reflex actions, which is of the same nature. For instance, Logre saw a tabetic general paralytic—it is true he had been previously shell-shocked—who, every time he heard the whistle of a shell, was seized by intense psychical and physical disorder, with sweats, wild excitement, and incontinence of urine. This, which to all appearance might have been purely emotional, was due in reality to tabetic lack of control over the sphincter.

Physical Symptoms.—In this early stage, those profound mental troubles that render the diagnosis of confirmed general paralysis an easy matter are limited to *lacunæ*, with possibly cerebral excitement, alterations of character, and a tendency to megalomania, or more precisely to a satisfied euphoria.

These are enough to give rise to suspicion and to require consideration, but not to justify a diagnosis. We must be on the watch for those physical signs also, the existence of which would add considerable weight to the psychological evidence.

Even from the outset we may often observe some weakness of the muscular tone, particularly noticeable in the face, where the least irregularity in the tonus of the complicated musculature changes the expression. Often the features look *drooping*, or if we tell the patient to make a grimace, we discover a disability. Less often a slight twitching of the facial muscles, especially of those of the orbit, may now be noticeable. These are fascicular twitches, slight or pronounced, a sort of wave running along the muscles. Generally the pupils are already indolent, with the Argyll-Robertson sign, or it may be, on the contrary, that there are excessive and oscillating reactions. Pupillary inequality is usually a later sign. The *tremor of the tongue* is at this stage a vermicular tremor, without movement as a whole. But there is also a slight tremor of the hands, and *especially of the whole body*, rapid and slight, but plainly perceptible if we place our hands on the shoulders of the patient as he stands upright before us. In doubtful cases these tremors are of important clinical value. Likewise auscultation of the heart often reveals a *distinct prolongation of the first sound*, of a somewhat bounding character, which serves to indicate the circulatory erethism.

The cerebro-spinal fluid shows lymphocytosis with albuminosis. The knee-jerks are generally exaggerated. Finally, the speech should be watched, so as to notice any characteristic impediments, which may sometimes make their appearance at this time, at least occasionally. By the forgetting of words or letters, and faults of spelling not in accordance with the education of the patient, the *writing* may also betray the mental weakness. The shakiness of the handwriting corresponds with the muscular tremor. Sometimes capital letters are the sign manual of commencing megalomania.

Forms and Progress.—Thus there is quite a series of clinical signs which usually point to a decision, once the thought of general paralysis has presented itself to the mind of the physician. But one of their characteristics is to be slight and fickle; so that we need not be surprised that many mistakes are made. For the rest, it will be remembered that when there has been a previous shell-shock, some of the physical signs, and some of the most specific among them, such as the spinal lymphocytosis, lose much of their value.

Again, it is sometimes a crisis that first attracts notice. It should be distinguished from an epileptic fit if it is accompanied by convulsions, or from an ordinary attack of apoplexy if it is hemiplegic. It will be remembered that those crises which the patient gets over quickly, without any paralysis being left behind, are quite likely to be complications of general paralysis. The subsequent progress may be slow, as it was with many paralytics before the war. But it certainly seems that on the whole our paralytics, and especially those that come from the army, progress much more rapidly. This observation, made by Charon, at Dury, during the last months of 1914, agrees exactly with my own observations. Certainly, it is specially applicable to the forms which are accompanied by excitement, but it also applies to those cases that began by a state of neurasthenia and depression. We shall see, in the chapter which treats of invaliding, the practical conclusions to be drawn from this.

As for the symptoms of confirmed general paralysis, there is no need to dwell on them. When chance leaves one of these sufferers in the army, it can only be because he has been debarred from a medical examination, which would quickly put matters straight, either by invaliding or interning him.

Treatment.—A simple hygienic treatment, relief of congestion, with intestinal antisepsis and complete rest, is always the most prudent course in order to delay the progress of the symptoms.

But a serious problem presents itself, that of *specific*

treatment. At first glance, certain considerations appear to be decisive : the prognosis of general paralysis being fatal, we risk nothing by trying it ; the syphilitic nature of general paralysis is proved by a positive Wassermann's reaction in the cerebro-spinal fluid in eighty per cent. of the cases, and by the presence of treponemas in the brains of paralytics; it is possible that an early and energetic treatment might be crowned with success.

On the other hand, it must be remarked that mercurial injections have now been proved to be therapeutically inefficacious, and may even be harmful ; that the arseno-benzols seem to be quite as inefficacious, and distinctly more dangerous, with the exception, however, of Swift and Ellis's method of intrathecal injections of salvarsanized serum, of which we have had no experience in France, but which has at least given hopes to American neurologists. The prospect is thus doubtful and gloomy even to the most sanguine.

But there is more. I have just said that there are several of us who have noticed that the general paralysis of these latter years has developed *more rapidly* than formerly. If we scrutinize our records, we find among these accelerated cases those patients who since the introduction of arseno-benzols into therapy have been treated by them for an already old-established syphilis. May that not have been a mistake ? In other words, the more remote the primary accident, the less harmless the treatment by arseno-benzols, and the less also is its efficacy. Gaucher has several times insisted on its admitted dangers ; and I have myself pointed out, in a communication to the Academy of Medicine, the precautions which seemed to me to be necessary.

These precautions, which would be legitimately applicable to any case whatever of general paralysis, become much more important in the case of patients who have been taken ill when in the army, and who may have been subjected to not only a cerebral shock on a certain day, but also to many slighter concussional shocks for quite a long time. It cannot be often enough

repeated that nothing is more difficult than to distinguish certain syndromes of shell-shock from general paralysis. Now, for these cases it is clear that nothing would be more dangerous than a congestive treatment, such as that produced by arseno-benzols, with neurotoxicity in addition. Thus, for this class of patients, who are curable if they are only shell-shocked, and if they are not subjected to any untimely treatment, all specific treatment, mercurial or arsenical, is absolutely prohibited, despite spinal lymphocytosis with albuminosis, and despite a positive Wassermann.

As for the other paralytics, when there is no evident co-existence of cerebral syphilitic lesions, treatment must be according to the particular case and the particular circumstances. I think it preferable to abstain.

V.—DIVERS ORGANIC AND ARTERIAL DEMENTIAS

There is no need to pause over these different arterial or organic dementias, mental remainders of alcoholism or of syphilis with vascular lesions, accidents of cerebral irrigation, over the dementias with lacunæ, or those of a vesanic nature. They are scarcely ever seen except at the rear, when, for example, a class of elderly auxiliaries is called up. These do not concern the army, except that they require immediate discharge. We shall consider this later on. I will simply mention that their chronic progress may be diversified by acute episodes, with mental confusion superadded, connected, it may be, with a transitory insufficiency of renal action. Therefore, we must not attribute to the exciting circumstances which produced this episode the whole of the psychic defect which persists after it.

CHAPTER III

SPECIAL CASES

THIS chapter relates to various cases in which the mental disorders form only a part of the clinical picture, and are overshadowed by more important symptoms of a neurological kind, or which raise problems of legal medicine and military utilization leading to those practical applications that will be discussed further on.

I.—TRAUMATIC CEREBRAL LESIONS

Here we shall leave aside, on the one hand, all those symptoms which are entirely neurological: motor, sensitive, reflex, and vaso-motor, and dependent on traumatic cerebral lesions; and, on the other hand, all the symptoms of inhibition, or immediate mental deficiency, coma, post-traumatic torpor, etc. We shall only speak of the obstinate and lasting mental disorders of those who have received cranial wounds.

Numerous studies have been made of them and the results have been summarized, particularly at a special meeting of the Neurological Society of Paris, on April 6, 1916, to which the reader may be referred for the full study of the subject (*Revue Neurologique*, avril-mai, 1916) and also at a meeting of the Surgical and Neurological Societies on May 24, 1916 (*Revue Neurologique*, juin, 1916).

To gain a clear idea of the mental diseases of those who have had wounds of the skull, it is advisable to remember that besides the direct lesions and loss of substance, caused by the passage of the projectile or of fragments of bone, there are very often slight infective

lesions. The following fact should be especially taken into account: all penetrating wounds from a bullet, and even all non-penetrating but violent injuries, affecting any one point of the cranium, diffuse their action over the whole extent of the encephalon. The skull is a closed cavity, completely filled by a liquid, and heaving practically inextensible boundaries. Thus, every blow which injures it produces symptoms of concussion. Hence the close analogy, not to say identity, between the later sequelæ of trephining and the syndrome of shell-shock, which I have described above.

Those with cranial injuries, therefore, have local disease in connection with their injury, and subjective disorder proportionate at once to the initial lesion, the infective complications, and the concussional element, and also more or less conscious mental disorders, which appear to be due at least as much to the concussional element as to the infectious one.

For purely anatomico-physiological reasons, there is no lesion which gives rise to isolated mental disorder, in which motor and sensory disorders are not combined. Again, there are many cases of the gravest material lesions (perforation of the two hemispheres by a ball, partial destruction of a lobe by a shell splinter) without any persistent mental disorder. As a consequence, the character and intensity of the mental disorders seem to have no localizing symptoms. However, the psychical sphere, owing to former anatomico-clinical experiments, has long been extended to the whole of the cortex.

On the other hand, it often seems as if there were some connection between the intensity of the subjective disorders complained of by the trephined cases, and the mental disorder itself, either because both are dependent upon the same cause, which in these particular cases would be persistent disturbances of the cerebral circulation, or else because the subjective disorders, which are painful, exert a depressing influence on the mental activity of the patient.

The principal subjective disorders are as follow.

Headache is the most general and the most constant.

The wounded usually describe it as a heaviness, which never completely disappears, though it is better at certain times, and which is apt to predominate in the frontal and orbital regions. Its principal characteristic is, that it becomes distinctly worse and accompanied by shooting pains in certain circumstances: *i. e.* when the patient stoops, or when he makes a quick movement, or a physical effort, or has to exercise attention. Likewise when he sneezes, coughs, or goes down hill quickly with the heels striking the ground, and when subjected to noises, particularly sudden noises, such as the blows of a hammer on iron, and the clang of machines. A strong light has the same effect, and so have moving objects, such as the wheels of a carriage, or those which cause some degree of visual strain, such as stippled or checkered prints.

All jolting is painful, and Pierre Marie, who summarized these troubles in his report to the Neurological Society, remarks that the underground railway is intolerable to many of those who have head wounds, because of the noise, the jerks, and the heat.

All intellectual effort is particularly painful, and in those who were accustomed to lead an active intellectual life, the discovery of this deficiency provokes a depression which sometimes amounts to melancholia. Sometimes these patients say that most of the time they feel as if they had a ring round the head, and that every now and then the ring distinctly tightens, and that then, for a very short while, they feel as it were a passing cloud. During that time they come to a stop in current conversation, they no longer see well, and they hear badly; then it all goes off.

These phenomena, which, to this simple degree, are fairly common, should be looked on as incomplete "fits of absence," that is to say, as an extremely slight degree of epileptic fits.

Dizziness is an allied symptom, but the visual sensation is still more distinct, with bright lights or circles before the eyes. It is accompanied by an indisposition similar to that described above, from

which I have separated it because the dizziness has no connection with the headache. It has also no connection with the seat of the lesion or with its gravity.

More rarely there are true *vertigoes*, with the feeling that everything is moving round. When the patients speak of vertigoes it is easy to ascertain whether it may not in reality be dizziness and similar phenomena.

Fits of Congestion are common. They aggravate the ailments, more especially the headache. It is unnecessary to speak of the deplorable influence of all excesses, not only of alcohol, but of regimen. Sexual intercourse has the same disadvantageous effects.

Mental Disorders should be divided into those that are *common*, making part of the ordinary picture, and those that are *rare*.

Common Disorders.—These are *inaptitude for all work*, lack of comprehension, and a feeling as if the "brain were stuffed" at the least effort of attention. Secondly, there are disorders *of memory*, not often very severe, but which are frequent in slight degree. After glancing over the military records, and the publications of Pierre Marie, Souques, Villaret, R. Oppenheim, and others, one might almost say that no case of trephining escapes this. These disorders are principally a disturbance of the memory of *fixation*, that is to say, of passing events. Nothing becomes fixed in the mind of the trephined case, because of the absence of the power of attention. There is, therefore, a close connection between his condition and that of the memory. It corresponds exactly to the aprosexia of confusional cases; which is not surprising, since the mental state of patients with cranial injuries is in itself a variety of mental confusion.

There also is a disturbance of past memories, *retrogressive amnesia*, not with respect to those events of the war in which the patient took part, but as regards all former memories, which it requires effort to evoke. Thus the rule is, that polyglots have forgotten, at least in part, even quite fluently acquired languages, remembering only their mother tongue.

Insomnia also is common, or the sleep may be disturbed by nightmares. It contributes to maintain a state of vague uneasiness, of insecurity, which exerts a sensible influence on the *character*. This is also affected by the headache, the incapacity or the disturbances of the sensorial impressions, and the oscillations of the intracranial vascular tension. The attacks of congestion are often accompanied by brief fits of anger and sudden impulses. On the other hand, emotionalism often attains to unexpected proportions in men who have hitherto had great self-command. News, good or bad, patriotic emotions, musical or artistic impressions, are sometimes received with floods of tears. Those of the wounded who have strong characters suffer because of this. "It is idiotic to be like that" they say when excusing themselves.

Rare Disorders.—These are an exaggerated edition of the preceding ones; they are morbid emotionalism carried to extremes. Among them is the *state of depressive melancholia*, or more rarely the *anxious* state with *delusional self-accusation*. I have seen several somewhat serious cases of this: among others, one in an officer of mediocre general intelligence, who also had jacksonian epilepsy. A cranioplasty executed by Boeckel considerably ameliorated the local condition, then the delusion disappeared; but the fits continued.

There may also be *chronic mental confusion*, or rather, a state of mental confusion from which the patient does not emerge, because his general resistance is lowered little by little. He ends by dying of exhaustion, no longer taking any nourishment, completely deranged and imbecile. In such a case one might suspect infectious complications, especially a cerebral abscess, and all the more so since these disorders may come on suddenly, several months after the injury, just as an abscess does.

However, autopsies often give negative results. Also the duration of mental confusion is too short for cases of this kind—it is demential disorder that carries off the wounded.

Finally, and somewhat frequently, there are difficulties of speech and disorders of the special senses, varying in intensity, and which, though traditionally considered neurological, should be mentioned here on account of the inevitable share that mental changes take in their production.

Aphasia may be met with even when there is no lesion of Broca's convolution, or of the sensorial regions of the cortex. It is, therefore, due quite as much to shock as to any precise localization. It is generally of serious import, not because the difficulty of speech is incurable, but because it is linked with a mental deficiency which is sometimes considerable. Even when it seems to be cured, we find, as Froment in especial has done, that there are very distinct sequelæ, such as alterations, more or less pronounced, in voluntary attention; an actual abolition of attention, manifesting itself when anything occurs to distract the patient; a lessening of the power of co-ordinating ideas; lapses of memory; a difficulty in remembering words and their correct spelling.

Dysarthria, at least in a slight and passing form, is a fairly frequent symptom. A peculiar disorder of the power of speech in which the voice becomes monotonous, and the words are uttered slowly and brokenly, may also be observed. This way of speaking recalls that of some pseudo-bulbar cases, and indeed it certainly seems to be dependent on some central lesion.

Concerning this series of disorders, we should bear in mind that, on the one hand, they leave behind them in many cases a doubtless temporary, but sensible, reduction of the general intelligence; and that, on the other hand, they are accompanied by a considerable increase of emotivity, and also of susceptibility to noises and disturbances. This indicates the precautions necessary with regard to the military utilization of these men, a subject we shall return to later on. We should most carefully avoid the use of toxic sedatives, remembering the deplorable effects of opium, for instance, on the injured cortical substance. Thus, in the course of

his experiments, R. Tripier found that, after the destruction of the sigmoid gyrus in a dog and the subsequent recovery from the resultant paralysis, he could reproduce the latter at will by injecting morphia into the animal.

We should continuously combat the intestinal auto-toxæmia and digestive toxins. The fate of these trephined cases depends greatly on the organization and discipline of the hospitals which receive them. Alcohol, which injures even the healthiest brain, has only too good a chance with them, and there is nothing easier than to provoke epilepsy, insane impulses, or a confused state, by the administration of even the most wholesome of appetizers to a trephined patient.

Despite the remarkable recoveries we meet with, of persons who have lost a considerable part of the brain, or who have recovered from the passage of a bullet through the head, cranio-encephalic lesions are undeniably casualties which demand a cautious prognosis. The patients who have the fewest after-symptoms are not necessarily those who were the least injured; they are those whose wound was the least infected, who were favoured by chance with respect to the surgeon into whose hands they first fell, and have no adhesions left between the cortical substance and its coverings.

These adhesions are a kind of cerebral cicatrices, of considerable importance in mental pathology, as Pierret has demonstrated. Whether extensive or limited, they act as a permanent source of irritation, and of circulatory and nutritive disturbance. They multiply the injurious power of every intoxication; they create an aptitude for the motor reaction of discharge—the convulsive fit and its psychical equivalent, impulsiveness. Their pathogenic character is such that it is often better to defer a cerebral operation, so as not to cause new cicatrices, and this is more especially the case with regard to jacksonian fits.

II.—MENTAL DISORDERS IN DISEASES OF THE NERVOUS SYSTEM

Here follow a few cases of no numerical importance, which are worth considering only because of the mistakes to which they might give rise. For this reason they require mention.

§ 1.—Cerebral Tumours

Thrice I have met with mental disorders specially characterized by great intellectual torpor, general indifference, and obstinate headache, which were the only indications of cerebral tumours whose subsequent development determined the diagnosis. The characters of the headaches which, we may say, are never lacking, and are dull and heavy, the frequent disturbances of the eyesight, and, if necessary, examination of the fundus of the eye, will enable us to eliminate the hypothesis of mental confusion, connected or not with some episode of the war. When there is a cerebellar tumour, or one of the ponto-cerebellar junction, disturbances of the hearing and of equilibration will decide the diagnosis. But this remains difficult in the case of tumours of the frontal lobes. If the presence of such a tumour is suspected, a lumbar punctiure should only be made with the utmost caution, and no more of the fluid taken than is necessary for examination. Sudden deaths have been caused by abrupt cerebral decompression.

§ 2.—Parkinson's Disease

There are early cases of Parkinson's disease, but slightly affected from the motor point of view, or, for example, only suffering from a parkinsonian monoplegia which permits of their being still used in the army. It is not uncommon for these imperfect forms of the disease to be accompanied by some mental disorders of a depressed type. This is not solely the result of the way in which the patients may be

dwelling on their condition. Slight fits of confusion and anxiety may sometimes be seen without toxic or medicinal intervention.

§ 3.—Insular Sclerosis

There are in the army many cases of false insular sclerosis, which are really cases of tonic and tremulous neurosis, and are caused by hysteria, or traumatic hysteria. But there are also some organic cases of insular sclerosis. They have a certain importance, as it is possible that among their number there may be officers who to all appearance have only some slight motor disorder, quite compatible at first sight with a sedentary employment. Now it should be thoroughly understood that, in the complex syndrome of insular sclerosis, the cortical substance is much more often affected than is generally believed to be the case. In this malady either fits of confusion or insane ideas, grandiose ones, may suddenly supervene, and the consequences of this would be very serious if, at the time, a possibility arose of the patient being called on to give orders. We are speaking specially of insular sclerosis slowly developed at a mature age, and especially of those imperfect forms in which complex etiological factors doubtless intervene—notably alcohol and syphilis—capable by themselves alone of causing mental disorders.

In cases of tremor, which may be localized or hemiplegic, we should, therefore, examine very carefully into the mental condition of the patient, so as not to permit those who are liable to serious complications to remain in any position of responsibility.

§ 4.—Tabes

Tabes is by far the most important problem presented by organic nervous diseases. Tabetics are numerous; there are some among the officers corps and also among the auxiliaries, who are kept in the army because they can be of use in an office, for instance, and concerning whom a too summary examination has led to

the declaration that they were unfit for marching or combatant service because they suffered from rheumatism. One would never have imagined there were so many unrecognized tabetics. Perhaps it may be that we are now better able to recognize slight cases of tabes, and especially doubtless because syphilis is often much better treated than it used to be, and many cases of tabes are less serious. That at least was the impression I had till lately. Then chance brought before me some serious cases of tabes, which, and this is specially noteworthy, were also premature cases thereof, and had been treated by means of arsenobenzols. So far as regards treatment by these last agents, therefore, the matter stands in much the same position as general paralysis.

The danger of "606" appears to be chiefly that of favouring congestive pressure on the nervous centres, and at the same time of subjecting them to a toxic action. Now, these ill effects are precisely those which most directly lead to tabetic mental disorders. These are of two types.

To begin with, there are gloomy thoughts, vague tendencies to melancholia, and to persecutory mania; these are connected with the pains, and especially with the deeply seated disorders of the coencæsthesia and the sensorial apparatus. In this type of the malady there is nearly always a corresponding toxic element. Purgatives and strict dieting will cause these to disappear; sometimes, also, they are favourably influenced by a lumbar puncture, as Débove has shown to be the case with regard to gastric crises.

The other type of tabetic mental disorder is an attack of megalomania with excitement, the tabetic general paralysis. Here there are two alternatives: if the inflammatory attack is a violent one, and also, perhaps, if we do not succeed in averting it, the illness makes swift progress, and the patient is carried off by a general paralysis which runs a very rapid course.

If, on the contrary, and this is much more common, there is only a mild inflammatory attack, after some

little time the patient recovers, and there is nothing left save a slight intellectual weakness. Thus, there are about the world, and also in the army, tabetics who from time to time have an attack of insane excitement for some weeks, during which they are general paralytics. And some time after we may meet with them quite fit again, except for some difficulty in walking. These tabetic types of general paralysis, with which Pierret has made us acquainted, and to which we have given the name of *regressive general paralysis*, may last for a very long time, and will show somewhat striking remissions. Certainly it would be difficult to keep even the mild cases in the army, and this should be avoided.

§ 5.—Hemorrhagic Pachymeningitis

We have already loaded alcohol with heavy responsibilities. Subject to exception, there should be attributed to it also the comatose symptoms, often preceded by a phase of distinct cerebral hebetude, of hemorrhagic pachymeningitis.

III.—EPILEPSY

In the army at the present time epilepsy raises serious problems, both theoretical and practical.

It is distinctly becoming more common. It sometimes gives rise to serious doubts concerning the real nature of the fits. It lends itself to simulation. It may declare itself by purely psychical symptoms leading to most serious consequences, and of which the diagnosis is always difficult. It may result from episodes of the war. It may be due to wounds of other parts than brain.

Frequency.—Even if we do not take into account jacksonian traumatic epilepsy, caused by a cortical lesion, even if we make as large an allowance as possible for the part played by neuropathy, pure and simple, in the convulsive symptoms of the shell-shocked and those subject to fits of all kinds whom we receive into

our hospitals, still there does not seem to be any doubt that the war has produced an increase of epilepsy. Many epileptics in civil life have already been invalided, and every day new cases present themselves.

When we examine closely into the matter, we find that it is more especially the number of fits which have increased, rather than the number of affected cases; and that the former are of a more severe type. In other words, the apparent aggregate increase is due to the fact that there was spread about the country a considerable number of undeveloped or masked cases of epilepsy, in persons who had never had a severe epileptic fit, but who did have, at variable intervals, slight ailments the nature of which was not recognized.

The increase in frequency is, therefore, explained by the fact that these patients, who were accustomed to certain ways of living, have had to change their habits, their diet, which for some of them is more carnivorous than formerly, have had their sleep disturbed, their rest broken; they have had digestive disorders, sometimes a degree of heart and circulatory over-strain, a factor of the first importance in the pathogeny of fits, and finally they have been subjected to two agencies, emotion and alcohol, which exercise a decisive convulsionary influence in predisposed cases.

It must be clearly understood that here emotion acts not solely by means of suggestion, but in a complex manner, possibly through the intervention of the circulatory system. As for alcohol, there is no need to dwell on its effects. As we shall see, the suppression of absinthe has brought about a diminution in the impulsive actions of alcoholic epileptics, but not to any great degree, owing to the injurious action of other spirituous drinks. And, indeed, it is specially from that quarter that we should look for the increase in the number of epileptic fits.

Diagnosis of the Fits.—The difference between the neuropathic or hysterical fit and the epileptic fits lies especially in the following characteristics: *in epilepsy* the fit may come on at any moment, or at fairly regular

intervals, but in any case without the intervention of any special incident. There is the initial cry, *pallor of the face, mydriasis*, the following of a tonic by a clonic phase without exaggerated movements or contorted attitudes, *involuntary micturition*, *biting the tongue*, with final comatose torpor, and consecutive hebetude. Certainly some of these characteristics may be seen in an hysterical fit, or even be simulated, although a real authentic biting of the tongue is hardly ever simulated. But those symptoms, such as the pallor and the mydriasis, which are not under the control of the will, are of great diagnostic value.

The state between the fits will also afford indications which can scarcely be mistaken if one has had any clinical experience. The neuropath subject to fits is always a neuropath, the evident emotivity of whose words and actions bear a very special stamp. The epileptic may be normal, only exhibiting a few minor features which at first sight are not pronounced enough to attract attention: such as an exaggerated obstinacy, a little impulsiveness, or grinding of the teeth during sleep at night.

Psychical Epilepsy.—The ordinary impulsiveness of the epileptic is, as we know, sometimes changed into automatic phenomena, into *second states*, which take the place of the fits, and may be either an attack of *furious madness*, blindly violent, and coming on quite suddenly, as the fits do, and in the course of which the patient may commit a murder, for instance, without having the least remembrance of it; or there may be more complex and lasting phenomena.

Perhaps the most common of these phenomena is the *fit of automatism* which lasts several hours, and during which the epileptic runs away. Suddenly he returns to himself, and is astonished, not understanding in the least what has happened. The automatic attack may last for several days, but such an occurrence is extremely rare and is doubtful, and no cases of it seem to have been reported since the war began. In any case the medico-legal problem it sets us is manifest.

It is all the more difficult, as we shall see, because certain observations tend to prove that both as regards the attack of furious madness, and the running away, the loss of consciousness may not be absolutely total.

By the side of these automatic fits a place must be made for the *delusions* of epilepsy. These belong to masked epilepsy, in which fits are not habitual, and their epileptic nature is often only retrospectively demonstrable, or else by the knowledge of other distinctly epileptic incidents. These are fits of *mental confusion* with hallucinations and dreaminess similar to those described in the section on acute psychoses. But they are accompanied by excitement, sometimes of an intense and maniacal type, to such a degree that Pierret and other authors have suggested that maniacal depressive psychosis may only be a variety of epilepsy.

When the delusional attacks come on in an epileptic who does have fits, they usually assume a different form. Coming on *after* the fit, and lasting for several days, they represent a psychosis of exhaustion, and are of a depressive and melancholic type.

Epilepsies caused by Peripheral Lesions.—There is no need of a reminder as to what jacksonian epilepsy is, or of the elementary truth that it may be caused by cerebral lesions not localized in the motor zone. We will remark in passing that it is perhaps not as common as might have been feared, taking into consideration the numerous cases of traumatic cerebral lesions we meet with; but epilepsy from cerebral or encephalic lesion is not the only kind.

The war has furnished some examples of a too often forgotten variety, which we designate by the title of "Brown-Séquard's epilepsy" on account of the researches by which he proved in 1869 that it was possible to produce epileptic fits in a guinea-pig by injuring the sciatic nerve. Mairet, Heitz, and Souquez have published observations concerning them, and we have observed two cases, one following on a wound of the nerves of a foot, and the other on a penetrating chest wound. These epilepsies were not developed

till several months after the wounds had been received, and were provoked by nervous irritation from the scars. So far, we have seen only convulsive fits without any mental phenomena, but their medico-legal importance is evident. My two patients had been looked on as malingerers, since they had not received any *cranial* wound to account for their symptoms. The prognosis of these cases should be guarded; it is possible that surgical operations might benefit them.

IV.—HYSTERIA

If we trusted to the titles of various foreign publications, especially Russian and German ones, there should be a considerable number of hysterical psychoses caused by war. This is not the impression we receive from practice in an important centre, or from French publications. But perhaps the divergence lies more in words than in meaning. The Russian authors, in particular, attribute to hysteria those emotive mental confusions which we have included in the general term of confusional states—the psychoses of shell-shock, and most likely, some of the states of polymorphous insanity in degenerates. With us, despite the discussions of the schools, the term hysteria is less comprehensive.

No doubt hysteria is a mental disease in itself, but the importance of the mental condition of hysterical patients should not be exaggerated to the point of looking on them all as suffering from grave disease, and especially not as such in the intervals between the paroxysms.

In everyday life, apart from the fits, the hysterical male, who is, however, a less common specimen than he has been said to be, is a "mythomaniac" and unbalanced. We shall meet him again in this double capacity a little further on. But mythomania—and we shall soon see the part it plays in a series of crimes—is by no means always a pathological phenomenon which the disciplinary authorities are powerless to

restrain. Far from it. It is the same with it as with the paroxysmal symptoms: they are involuntary chiefly because the patient does not try to resist them. A firm and active psychotherapy is always successful. The convulsive fits of severe hysteria are not simulated, but when the patients are placed in some institution from which they cannot get out at will, and have been well warned that *fits are absolutely forbidden*, these last disappear. The chief point is to be sure of one's diagnosis, and not to confound cases of hysteria with those of epilepsy or simulation.

Although there are mental confusions and delusions of emotional origin among patients of an hysterical temperament, yet in current practice there are hardly ever any purely hysterical psychoses properly so-called. For the rest, the emotion operating in such cases is not necessarily fear. H. Claude, M. Dide, and Lejonne in particular have published the case of a man without fear, undaunted, whose mind gave way under an accusation of theft. As for the deeds and delinquencies of mythomaniacs, these concern the particular case, and are to be considered solely from the medico-legal standpoint.

En liaison, if one may say so, with hysteria there is *somnambulism*. It is not at all common to any great degree, but is not exceptional, and I have seen several young soldiers whom inquiry proved to have been constantly somnambulistic since their childhood, and on whom no therapeutical treatment had any effect. Finally, as a matter of course, however good may be the will of the patient, the circumstances and risks of war exercise too strong a counter-suggestion to allow of anything he hoped for from them.

Whenever the occurrence of fits is positively proved, we must forgo keeping on these men in any employment whatever. The responsibilities they entail far exceed the services they may render. We are inclined to say that "providence takes care of the somnambulist," and to think that the man who walks about on the barrack roofs in his sleep, at night, will never

fall. This is a mistake, for there have been accidents; and the somnambulist, though generally quiet, may injure others as well as himself, or even more so.

V.—PSYCHASTHENIA

The patients who figure in this section have not a good record. As they do not have convulsive fits, we are in less of a hurry to get rid of them than we are of epileptic or hysterical cases, and once they are kept in the army we are more inclined to look on them as exaggerators or simulators, all the more so because they worry the doctors and commanding officers about their sufferings as much as they do themselves. And yet they are very unhappy folk, all the more so because the basis of their mistakes, of their fixed ideas, and their obsessions, is *fear*, an inadmissible and justly stigmatized defect at the present time. They are of all sorts and all kinds, of every age and every condition, and they are, what sometimes makes the solution of the problem more difficult, of every degree of physical resistance. What must be well understood is that along with the other neuroses this type exists, and that it constitutes the true neuropaths, the seriously affected neuropaths, those who are half-way between sanity and madness. The variety of their clinical appearance, and the somewhat frequent difficulty of their psychological examination, have wronged them. They are often ill-understood and, above all, wrongly judged.

We can only indicate a few types here, but they will serve as guides by analogy.

Neuroses of Anxiety and Specialized Phobias.—For convenience, and especially for brevity of description, we may combine the paroxysms of anxiety, with marked tachycardia and hypotension, indefinable uneasiness, and extreme vaso-motor reactions coming on without any apparent cause, with those of the same kind that are brought on by a cause always the same. Both of these kinds of patients suffer severely, and in

their cases treatment does not produce any brilliant results. The antecedents enable us to fix the diagnosis and to eliminate the hypothesis of simulation. We nearly always find hereditary antecedents and affected collateral relatives. In these cases the hereditary tendency is not only neuropathic: it may be also distinctly insane. It is the children or nephews of the unbalanced, of impulsive alcoholics, of the intoxicated, of general paralytics, of those with persecutory mania, or premature dementia, etc., who suffer in this way. In some cases of hereditary neuropathy the inheritance is close. The fear may be the same, or nearly so, as that which poisoned the life of the ancestor.

Personal antecedents also should be taken into account. There are, among others, four which are frequently met with in the course of our observations; these are, in the order of increasing frequency, and according to my personal impressions, which may need confirmation, as follows: *alcoholism*, *typhoid fever*, *syphilis;* finally and specially *cranial traumatism*. There are few alcoholics among the number, those who had had typhoid seemed to be those in whom the nervous system of the heart, as well as the myocardium, were still affected by the toxin. As regards syphilis, we are only concerned here with the depressing general influence it has on the patients, and not with the special dread connected with it, syphilophobia.

But I believe that great importance should be attached to cranial traumatisms. Falls from a horse or motor-car, and especially motor-cycle accidents, are accidents which may leave the victim "cracked." And in that case the malady will take the form of fits of anxiety. Such a patient, otherwise normal and *even courageous*, will have a nervous dread of open spaces, *agoraphobia*. I have seen men who had behaved well under fire because they were in direct contact with their gun or their ammunition wagon, seized, when on the parade ground at the dépôt, with an excruciating and paralysing dread. The reality of

their sensations may be appreciated by an examination of the circulatory apparatus, which is in a state of erethism, with arterial disturbance and hypotension. We may also sometimes find a touch of exophthalmic goitre.

Others of them have an anxious dread of railways, especially of the tunnels; while the phobia of others, who are certainly not the right people to be at the front, is an irrepressible desire to wash their hands all day long.

Others are assailed by doubt, and are always verifying the actions they have just performed. Instances are extremely various. For all of them there is but little hope from treatment. The only useful question is as to how they should be employed, which should generally be in the auxiliary services.

Hypochondriacs.—Hypochondriacs are pretty nearly all imaginary invalids. They also present that strange peculiarity of evincing, respecting some insignificant or non-existent ailment, an extraordinary pusillanimity, whereas at the front they had shown themselves capable of fulfilling their duty in the most creditable manner.

Hypochondriacal ideas may be riveted upon an organ, or some illness or the other, but some among them are of a special tenacity and intensity.

The dread of *syphilis* is one of the number. The recent spread of syphilis has perhaps contributed to it, but it did not create it. This is a very old phobia; its manifestations must often have been explained as depending on "syphilitic madness," an inaccurately comprehensive term, which lumped together symptoms, some of which, as in the present case, were solely neuropathic, while others were mental confusions of the secondary period, as to the nature of which much might be said; and, finally, others were those of general paralysis. Of this disparate assembly, nothing remains nowadays to the direct account of syphilis, save the last. Moreover, the problem of general paralysis is a complicated one. But in all these cases nothing

remains of the opening syphilitic insanity. Mental confusion of the secondary period, which is often seen in the strongly predisposed, generally seems to be an emotional mental confusion, as examples furnished by Colin and Lautier most convincingly demonstrate.

As for syphilophobia without any psychosis, properly so called, everything indicates that it is solely neuropathic: the temperament of the patients, the existence of other morbid fears in them, or in their near relatives, and especially the fact that it is never as strong as in those who believe themselves to be syphilitics, but are not so. However that may be, they are often great sufferers, for whom the dread of using contaminated objects renders life in the regiment impossible as long as they are still living in fear of contamination, and who, on the other hand, go positively raving mad when they believe they are infected. Not only do they importune the doctors to apply their most modern and energetic remedies to them, but, predestined victims of quacks, they go to these latter to get various drugs injected into them, the action of which is sometimes injurious to their general condition. Practically they are inutilizable, despite the apparent triviality of their disorder. Besides, the really serious cases scarcely ever recover: some of them terminate by suicide.

We might almost say as much of the psychopathy of micturition, of all the spurious *urinary* cases, who complain of a stricture, charging with all sorts of responsibilities on an old blennorrhagia, long since cured, and having left no trace. It is the same also with the cases of spermatorrheacs, true or false, who are only genitally obsessed, sometimes with former venereal excesses—or more often with timidity of the normal act, misogyny, and solitary practices. These patients are more common than is generally believed. If they are of robust constitution, which is unusual, we may try to leave them in the combatant forces, in the somewhat slender hope that the events of war may serve to turn the current of their thoughts. But their

employment is more difficult if they are weakly. A little bromide of potassium in small doses, and cold hydrotherapy, with a strengthening of the general condition, are rational methods of treatment that at most are only efficacious in slight cases.

VI.—UNBALANCED CASES

We come to a group of patients who, even in peace time are the plague of the army, and with regard to whom, either as medical administrator, as medical practitioner, or as expert, we are incessantly caught between our professional duty and regret at not being able to do more. *These people really are ill*, and this should be thoroughly understood from the first, so that they may be distinguished from ordinary defaulters. Unluckily, the nature of their illness inevitably leads them to commit either offences against the law or anti-social acts, and on the other hand, their condition is such that it always demands a very difficult examination to determine their moral responsibility. We shall see this side of the question in the chapter on legal medicine and the difficulties attending its solution, and experts' reports upon it. Now to specify them as exactly as possible from the clinical point of view.

These unbalanced cases must be clearly distinguished from those of mental debility. They are not cases of the latter who have "taken a bad turn." These are of quite another kind. In cases of mental debility, the development of the brain was, at a certain stage, checked as a whole, or rather it has always been behindhand. In unbalanced cases there has been inequality of development of the cerebral faculties: some have remained rudimentary, quite as much so as in the cases of mental debility, while others are normal, in some cases even above normal. They are intelligent, and as they have extra qualities of imagination and ingenuity they may sometimes even appear to be very intelligent.

But balance is completely lacking in them: they have no common sense, no concern as to the results of their actions, no foresight, no persistence, and no taste for work. So much for their own selfish interests, now for those of others: they are totally incapable of feeling affection and of the most natural reactions of moral sensibility. They are heartless. They have not the least sense of honesty. As children, from the first, they were vicious and liars. In adolescence they go on to stealing, swindling, and impulsive outrages. Before the magistrate or the doctor they volubly with vanity recount their bold deeds. Once childhood is passed, no measure, no authority, has any beneficial effect on them. They are difficult to manage even in their youth: that over, nothing can influence them.

In especial, they are impulsive, and it is generally because of that that they commit offences. Once their instincts are unchained, they never check them, and indeed it is doubtful if they could do so, for reflective will-power is completely lacking in them. Moreover, as has been shown by Surgeon-Inspector Simonin, this impulsiveness is increased by alcohol in even relatively small doses. We must, therefore, expect them to develop solely in accordance with their automatic inclinations. Likewise, they are unboundedly selfish in their conduct, and indisposed to make any concession whatever to social order; hence it follows that they are as unamenable to kindness as to repressive authority.

They are beings outside humanity, profoundly abnormal in everything concerning the ordinary affinities and sentiments of a regularly developed man. Their mental condition, which is generally tainted by alcoholism, may also be complicated by disorders such as obsession, fixed ideas, tendencies to persecutory mania. It is not exceptional for them to commit suicide, through a sudden impulsion rather than by a prolonged melancholic descent. They are, however, quite capable of displaying real courage.

In peace-time these men are excluded from the army

because of their mental condition or their convictions, or else they are incorporated in the African battalions, in which Granjux, Jude, Rebierre, Boigey and other military surgeons have so thoroughly studied their behaviour. Since the war they have made the task of the medical authorities and the judge-advocates of the courts-martial a heavy one. Consequently we shall meet with them again when we come to consider the medico-legal problem and that of discharge.

VII.—NATIVES OF THE COLONIES

We can only lightly sketch the pathologic psychology of the various native races of our Colonies and Protectorates that are at present represented in our armies. The principal stumbling-block in every case is the difficulty of understanding and being understood, as even the best of interpreters is not worth much more than a simple silent observation. Two facts, however, stand out: a few of these men feel out of their element and suffer from nostalgia. Also a number of them, very limited among the Mussulman troops, but considerable among the black and yellow Algerian workmen in the war-factories, show symptoms of alcoholism. Under the influence of alcohol, acute psychoses of two types may declare themselves: hallucinatory mental confusion with great excitement and maniacal conduct, and the depressive type with refusal of nourishment and attempts at suicide. Beyond that, to judge from observations in a hospital through which many colonials have passed, and from reports from Porot's hospital at Algiers, there are but few cases.

Porot and I have both seen very distinct premature dementias, and delusions of a mystical character in a Mussulman, without any great exaltation, and without any decided sign of mental confusion, so that a toxic influence was not probable. Lautier has published an interesting case of this, coming from H. Colin's hospital.

We know that old-established observations have recorded the immunity of the native races from the

complications of parasyphilis, a fact which is all the more striking since, among the colonials, syphilis is sometimes extremely malignant and is very prevalent. Of late years this impression has been transformed, or, if one may put it so, confirmed by its own modification. Warnock at Cairo and our army surgeons in North Africa have most clearly seen that this immunity disappears from the moment that the populations, adopting European life more or less, and in any case losing their primitive calm, take to drink, overwork themselves, and overtax their brains. My impression—which depends solely on talks with medical men, which were instructive, but lacking in objectivity—is that the present war will still further confirm this idea, so that once again that etiological formula of general paralysis established by Krafft-Ebing, "syphilization, civilization," may find itself justified.

At all events it is most regrettable that the measures decreed against the sale of drink to the colonial workmen should be, in many parts of the country, if not looked on as a dead letter, at least very inadequately carried out. They should have enforced penalties against those licensed victuallers who contravened the law. These penalties would have been all the more efficacious since, as regards the Mussulmans, Ramadan would have come to the assistance of the authorities. With a general closing after sunset, during the hours of night when the fast is suspended, and the permanent closing of all transgressing public-houses, we might not only have avoided for these people a physical and moral contamination, the results of which, when they return to their own country, it is only too easy to foresee, but also have gained useful experience concerning the French consumption of drink, and saved alcohol for national defence. But the blindness or impotence of the Government with regard to the question of drink has not allowed of this. M. Albert Thomas has issued excellent circulars on the subject, but unfortunately he was not permitted to carry out the measures he ordered.

PART II

PRACTICAL APPLICATIONS

CHAPTER IV

JUDICIAL LEGAL MEDICINE

THE recognized existence of mental disorders has, in the army, practical consequences with respect to the utilization of the patient. But there is sometimes a penal as well as a medical question to be settled. Military life, especially in war-time, carries with it so many opportunities for breaches of discipline that it is inevitably through the occurrence of one of these transgressions that a certain number of mental disorders are discovered or suspected. It is for this reason that the practical applications of the preceding medical data will contain two chapters, viz. *Legal Medicine*—which we will call *judicial*, to distinguish it from that concerning the reports of the invaliding medical authorities—and *Military Discharges*.

But there is a preliminary question : in order that the following indications may have their full use and value, either from the standpoint of penal responsibility or that of the ultimate destiny of the patient, it is necessary that the experts, magistrates or members of commissions, should feel themselves to be on the same solid ground as ourselves. It is particularly necessary that there should be no doubt as to the reality of the disorders under discussion. Hence it is advisable to clear up the question of *simulation*.

I.—MALINGERING AND UNRECOGNIZED LUNATICS

Even in peace-time, the army is a school of malingering, which only those are ignorant of who have not lived in it. The regimental doctor, accustomed to being on his guard against the little dodges of the trooper who wants to escape drill or fatigue duty, the officers, and especially the non-commissioned officers, from whom the purpose of the sham invalid cannot be concealed, inevitably end by becoming extremely sceptical with regard to all those ailments that have no positive or recognizable foundation.

In war-time, for only too evident human reasons, it is greatly to be feared that there is a considerable increase of malingering; and on the other hand, any weakness or negligence in repressing it becomes a crime against the interests of the nation, which takes precedence of all else, as well as against those who are giving their lives for their country. Consequently, in the minds of the commanding officers of all ranks, and in those of the doctors, all alike passionately devoted to duty, a firm determination has become developed not to be taken in by malingerers. So, especially in the earlier days of the war, an important number of mental patients were at the least regarded with suspicion, and some fell victims to more serious mistakes. Nowadays, circumstances are more favourable to continuous observation, and events have served to enlighten the minds of the commanding officers and the doctors. They prove that those who will insist on seeing a malingerer in every mental case would be making a very silly blunder, for the following reason: what was simulated in the army in peace-time, and what are still simulated sometimes, are organic diseases, and especially functional disorders, such as pains, inabilities, paralysis, even nervous fits, but mental diseases scarcely ever.

The proof of this? Read the observations of

alienists on the interned soldiers, such as those of Antheaume and Mignot at Charenton. Out of 101 patients there was not a single malingerer. But, you may say, this applies to men who have been already sorted out and submitted to a close medical examination. Let us look at the inverse proposition. Nowhere is malingering so widespread as in the special disciplinary corps. Jude's book on the degenerates in the African battalions describes in detail the infinite variety and ingenuity of those patients. *Now among them there is no simulation of mental disorders.* And yet these men are defective, excitable neuropaths, who have daily under their eyes the non-simulated eccentricities of some of their comrades.

This has been demonstrated by all those alienists who have studied in its entirety insanity in the army; it is the express opinion of Régis, who, besides his own personal clinical experience, has certainly had the maximum of documents pass through his hands since he inaugurated the science of military psychiatry. It is also the opinion of Pactet, of Rayneau, of Taty, of Chavigny and of Haury. It is explicable by military reasons, and still more by general reasons.

The soldier who is possessed of sufficient will power and perseverance to simulate desires his freedom above all things Now to simulate insanity would lead either to a court-martial or to internment. And those who are sane, and especially those who are nervous, are afraid of mad people. Every day we see the proof of this in the sorting centres, where unavoidably, even if only in passing, those who are simply psycho-neurotics find themselves in contact with actual mental cases. The coward who longs to keep his skin intact is as afraid of the lunatic asylum as he is of the front. But the true reason is, that even in civil life madness cannot be simulated. The part is too difficult a one to play, and it is one in which there are too many chances of being found out, precisely because of the inevitable examination by specialists who know a great deal more about it than you do. We almost

admire, and we cite as historical curiosities, those malingerers who have succeeded in taking us in for any length of time. Nearly always a person who plays the madman gives himself away straight off. It is generally believed that madmen are wild and excitable in their behaviour, so the malingerers think it necessary to speak and to act in an absurd manner, gesticulating ridiculously, replying at random to questions addressed to them, and sometimes systematically giving answers exactly the opposite to those which should be given, which implies an intellectual effort that contradicts the incoherence they display.

And even this last characteristic, which at first sight seems to be decisive, may be disputable. It is not so much through present day clinical observations as by the reports of alienists of the preceding generation that we become acquainted with those cases of simulation in which preposterous answers are given. Now, there is a peculiar mental condition, essentially pathological, generally designated under the name of Ganser's syndrome, which does consist of just giving absurd answers. It is generally connected with premature dementia, that is to say, with a psychosis congruous with the age of many insane soldiers, and very difficult to diagnose, as we shall see later on. Thus, even if by some very rare exception we have before us a patient who, after thorough examination, seems to be simulating mental disorders, we should remember that a mistake is possible, and that to put the patient under observation in a special department is absolutely necessary. It has been said with some truth, that to practise simulation one must be a little mad already. To some extent that is the fact, and we shall see further on that cases of mental debility do simulate, not insanity, but bodily illness.

We are often tempted to employ severe methods in a case of presumed malingering, such as the douche, deprivation of food, or an electric battery, this last having superseded the red-hot iron. *These methods are always useless, and their employment, which is*

dangerous in cases of true insanity, is inexcusable. The patients who are really affected by mental disease are not hysterical. They are essentially not amenable to imperious suggestion. The chance, which after a conscientious clinical examination is an extremely slight one, of finding that we are dealing with a malingerer does not in any way compensate the disadvantages of using violence on patients.

We can obtain much more valuable indications by observation pure and simple, that of the physical condition being included. We should make a note of the considerable clinical importance of *insomnia*, which cannot be simulated, and which is rather common, especially in acute cases. We should not be unduly surprised at the lucidity of some of the patients, especially the persecutory ones and certain cases of premature dementia, lucidity which is in marked contrast with the insanity of their ideas in other respects.

There is a peculiar mental disorder in respect of which simulation is easier, and that is *amnesia.* The existence of transitory confused conditions, toxic or emotional, is consistent with short fits of amnesia, interpolated between apparently normal periods, and which may appear suspicious, especially if it is to the patient's interest not to remember what was happening at the time, while he was running away, for instance. Here, again, it is desirable to look for those physical symptoms that may allow of a retrospective reconstitution of an episode of mental confusion. The examination may also reveal that the patient is of an extremely neuropathic temperament—of an " hysterical " constitution. In that case, and only if there appears to be amnesia, a doctor versed in the practice of hypnotism, operating in a specialized centre and in the presence of witnesses, may try to hypnotize the patient, and make him recover his memory during the hypnotic slumber. Hypnosis does seem to be a good method of curing hysterical amnesia. *But hypnotism should never be employed except in cases of hysterical dumbness and*

aphonia, and for the rest we know that real mental cases are very refractory to it. Also, in any attempts at hypnotizing we should be very careful not to suggest to the patient any declaration or information which we may particularly wish to get from him : such as the avowal of a fault, the denunciation of a comrade, etc. Since the consequences of an imprudence or a blunder in such cases may be very serious, we should be ultra cautious.

By the side of amnesia a place must be made for *dumbness* and *deafness*. Properly speaking, these are not mental disorders. In fact, they belong rather to the neurological department than to that of psychiatry. But besides the fact that these departments are very often united, it must be borne in mind that dumbness and deafness form part of the syndrome of emotional shock, and sometimes, it may be, of a syndrome of shock in which the organic element greatly predominates over the psychic element. Now, it has been proved that some of these deaf or dumb patients are malingerers. Sicard, in especial, has had experience of this. However, the number of these malingerers must not be exaggerated. It is infinitesmal in comparison with the *bona-fide* hysterical deaf-mutes. Besides, in these cases it is not so much malingering as persistency : the patients, to begin with, really were deaf and dumb, and they recovered, but did not reveal their recovery.

This fact in particular rightly decides the question of simulation. It may be summarized thus—

Practically, there is no such thing as complete simulation of mental disorders. There does exist a somewhat widespread simulation of organic nervous disorders, both functional and sensorial.

This simulation, of which patients who are really affected by mental disorders may be guilty, consists still more of persistency and exaggeration than of simulation properly so-called. It is a simulation of *fixation* rather than of *creation* according to Sicard's formula. In an article by Sollier there is some par-

ticularly interesting information on the subject of this persistency in functional nervous disorders.

The previous existence of an organic disease on which the neuropathic phenomena are grafted, and then modified into less genuine manifestations, has led to the comparison of this class of patients with that of labour casualties. As the patients are nearly always wounded, or at the least shell-shocked, this is a legitimate comparison. A formula of Dupré's correctly indicates the successive stages: accident, emotion, suggestion, exaggeration, simulation, claims. But we see how, to reach these cases of simulation, we must turn aside from mental diseases, properly so-called.

I have mentioned that among these utilitarian exaggerators there may be patients who really are affected by mental disease. This is the case with the *feeble-minded*. Laignel-Lavastine and Courbon, among others, have clearly pointed out how they conduct themselves. The feeble-minded are self-willed and lack moderation; their exaggerations are obstinate and carried to excess; it is their improbability which betrays them. Their attitudes are counterfeited; their movements affected. "They are not movements but contortions. Limping becomes a plunge, high-stepping becomes the goose-step, trepidation becomes a pawing of the ground." Laignel-Lavastine and Courbon further point out that the exaggeration of the feeble-minded may very well be explained by a sort of mendicity which is familiar to them in civil life, and whereof experience has taught them what profit they may gain from it. The feeble-minded man, vaguely conscious of his social inferiority, willingly exploits it, by seeking to excite public pity. He habituates himself to a servile and begging humility, to which he remains faithful under all circumstances, lacking as he is in both critical sense and personal dignity. It never strikes him that the compassion he insists on arousing is very much out of place in war-time.

Worse than the exaggeration of the feeble-minded is the complete simulation of those who are actually

insane. On the eve of this war, Haury reported the case of a soldier who had simulated total amaurosis of one eye, and who was also, according to all the evidence, an authentic case of primary dementia. Fortunately such cases are rare, for they greatly complicate the task of the experts.

A last word concerning simulation and exaggeration. In the neuro-psychiatrical centres we sometimes receive men sent to be examined with respect to their mental condition, with a provisional diagnosis of pithiatism or exaggeration, and having no tendency to hysteria or simulation. They are usually cases of neurasthenia through a constitutional organic debility, or caused by tubercular infection. Not infrequently they are men whose circulatory system has been overstrained through the fatigues of the war or by a shell-shock, and to whom any effort brings on extreme tachycardia, which is often too hastily diagnosed as neuropathic.

In any case, the examination of these "neuroses" of the circulatory system, when it is made with modern methods for measuring the functional efficiency of the heart (arterial pressure by Pachon's oscillometer, Lian's test, etc.), shows either a diminution of the myocardiac resistance, or complex phenomena such as Basedowism. Thus there is real functional disorder, and not mere nervousness, or more or less conscious exaggeration.

Unrecognized Lunatics.—Thus in military psychiatry there is no great danger of our mistaking a man who is really ill for one who is not so. But we do often run the risk of failing to recognize the pathological mental condition of a patient. As Grandjux said in 1899, in defaulters "the commanding officers find in indiscipline a cause which is so natural, and which explains all that has happened so well, that they never think of asking themselves if there may not be another one." And Haury, too, has said "the commanding officers may not know that in reality there is nothing which more resembles a guilty or perverse action than a morbid

action, or a guilty man than a lunatic. And they do not suspect that in the army, where the number of offences against the law and the consequent repression is very high (for the very reason that there are so many more occasions there than elsewhere, owing to the multiplicity of rules and regulations in the regiment, and to the immediate need of prompt repression which emphasizes them), there are very many patients who anywhere else would be scarcely looked on as criminals, or punished as such." (*Les Abnormaux et les Malades Mentaux au Regiment*, p. 252). These lines written in peace-time find their justification in war-time, and are applicable at every turn. Régis, Pactet, and Colin had in former times made veritable discoveries in military prisons. It is also on account of the necessary repression that, since the war, the subject of unrecognized lunatics has come to the fore. Already, on the occasion of the passing of recent military laws, Parliament had shown what importance it attached to the provision of numerous psychiatrical investigations. Circumstances have doubtless led the military courts to share this impression. At the Lyons Centre the judge-advocates of the courts-martial are always asking for more and more expert examinations. Certain cases, in which the judge-advocate at first sight may have seemed to be over-scrupulous, have revealed distinct pathological states of which the first outward sign, if one may say so, was the default for which the patient was being prosecuted. Among the mental disorders which most easily pass unrecognized because of the apparent sanity of the patient, a special place should be made for the early stage of general paralysis in its " medico-legal " phase, for premature dementia, chronic persecutory mania, and epilepsy.

On the other hand, there are two classes of soldiers in which we are sure to find unrecognized lunatics if we look for them—those of the voluntary recruits of the days before the war, and those men arrested as simple absentees.

I purposely say, voluntary recruits of the days before

the war, for they were very different from those voluntary recruits, men of every age and free from all military obligation, who enlisted in response to their country's call. Among these latter we should scarcely find more than a few unbalanced minds in search of adventures. The average level of the volunteers was a very high one. But the volunteers of the pre-war days, the sons who were "the despair of their parents," the young scamp who never would work and whom they put into the army to get rid of him, or yet again, the dare-devil who wanted to see the world—among all of them there was a large proportion of excitable and unbalanced neuropaths.

As for the "simple absentees," whom Haury has studied with a meritorious and fruitful perseverance and penetration, what a collection of complete imbeciles, cretinous idiots, and feeble-minded folk, who did not appear before the military tribunals because they had no relatives and lived like savages in their own country, knowing nothing and understanding nothing; what an *omnium gatherum* of cases of premature dementia, of youthful persecutory maniacs, of impulsive alcoholics, of persons more or less useless and dangerous, they are!

II.—THE FUNCTIONS OF MILITARY PSYCHIATRIC EXPERTS

The functions of psychiatric experts in the army assume two principal forms: an act of routine duty, when the doctor is asked by his hierarchical chiefs, or by the commanding officers, to furnish a report concerning some special patient; and a formal act of a judicial character, when it is the result of an order from a judge-advocate, or is made after a previously administered oath.

It is unnecessary to emphasize that the professional conscience is pledged to an equal degree in either case, but that in the drawing-up of the judicial expert report the choice of terms should be most carefully

considered, since the reports may afterwards be read by officers who are not necessarily acquainted with medical terms or with the practice of psychology.

If possible, the papers in the case should be procured, and *thoroughly* well studied. It is not safe to limit oneself to just looking through them on the corner of a table in the judge-advocate's office, in the midst of the noise and the conditions, so disadvantageous for close attention and reflection, in which the army services are generally carried on. We should not necessarily rely on the early information gathered from the corps, and we should not hesitate to ask the judge-advocate to call for verification of it, and to make inquiries concerning the accused from the police of the place he came from, or from his employers. We should also interpret this information, the terms of which are often clumsy and inexact, and of which the gist itself should not be assumed to be correct except with extreme caution; but from which we may gather some detail which throws light on the whole subject.

We should not content ourselves with the information, which is nearly always negative, with respect to alcoholism. We should look for it in the party concerned and his ascendants. We should try to review as exactly as possible the man's civil life before the war, to know what his earnings were, and thus, for example, we may find that, though still cutting a good figure, he was decidedly feeble-minded, and only capable of earning his food and lodging. By means of the papers in the case, and interrogation of the accused, we should remodel the preliminary investigation with this idea: *define the motive.* In the criminal proceedings of civil law it is very rarely necessary to ask this question, but in these military proceedings a medical witness cannot but be struck by the number of offences, the consequences of which may be most serious for the person committing them, and for which there is no apparent motive. This last fact is often a valuable presumption of mental disorder, and it may happen that the crime can only be explained by

such a disorder, and that would serve to solve the problem.

The papers concerning the preliminary investigation are generally excellent as far as the judge-advocates are concerned. The inquiries in the regiment, the miscellaneous information, and the purely military reports are often influenced by an unconscious prejudice, which puts things in a bad light and misleads investigation. But the commissioner-judge-advocates of the armies, the captain-judge-advocates, their deputies, and even their clerks at the courts-martial at the rear, are often members of the legal profession—magistrates or advocates who have had experience in such matters and are accustomed to cross-examine witnesses. As the duration of the war has gradually brought about the return of those best fitted to fulfil these extremely exacting duties, the papers in the case have improved, and the task of the experts has been greatly facilitated. My colleagues and I have met with the most kindly, the most intelligent, and sometimes the most instructive co-operation on the part of the various judge-advocates from whom we took our instructions. Therefore the expert should not hesitate to speak out, to state his reasons, and even his scruples. It is advantageous, however, especially if the case should be sent for trial, to give very clear, very short, and very decided conclusions. The judges of the courts-martial are very different from the judge-advocates. We must not expect from them either juridical experience, psychological subtlety, or medical knowledge. They are extremely conscientious, with a very high, but very rigid, sense of duty. Their duty is not to interpret, but to act upon testimony or opinion. It is therefore necessary that they should not be able to make any mistake with regard to that of the expert.

If we have at our disposal a hospital ward in which conditions will allow of our applying the regulations for prisoners, and if we have a staff capable of surveillance, and especially of observing the accused, we should admit him into the hospital. The examina-

tion could be made under infinitely better conditions than in disciplinary quarters. For the rest, a mental examination should always be made partly unknown to the party concerned. Never will you be better able to satisfy yourself whether a person is insane, or simply a sane criminal, than by observing him secretly, without his being aware of it. Have him watched in his sleep, and notes taken of any indications which may be gathered from his dreams. Examine him carefully several times from the physical standpoint. Do not fail to notice any nocturnal epileptic fits which have led to the soiling of the bed, or the tongue being bitten. Do not neglect to analyse the urine, with regard to sugar as well as albumen. Read the letters written by the accused as well as those he receives.

When you are ready to make your report, when your mind is made up on the matter, do not hesitate, if there is anything still not quite clear to you, to go and talk it over with the judge-advocate before you take up your pen. Find out from him what penalty the man may incur, consider with him whether, in case of condemnation, the prisoner may not be reprieved to the front, may not be employed, providing his physical and mental health allows of it. Then, with full understanding of the possible consequences of your report, draw it up with military brevity, and as clearly as possible. Some people will tell you that there is no need to concern yourself beforehand with what may be the result of your report, that you have only to give a yes, or a no, as to the sanity of the patient. Do not listen to them. You are a man, and it is as a man you should judge, for after all, it is you who are the judge. You must show no weakness, but neither should you allow yourself the slightest negligence. And, considering the formidable duty that the country has placed in your hands, it would be negligence to decide without having duly weighed the purport of your verdict, and thought of the fate you consign the man to. Whether from culpable indulgence, or from excessive severity, you may make a

mistake if you do not know just what you are about. If the man is one of those inutilizables of whom the army must be rid, and his responsibility *nil* or nearly so, be sure to say that his discharge is necessary, and that under no circumstances would a reprieve to the front be advisable. There is a chance that you may receive an order to present the patient for discharge, after which the delivery of the order of discharge will oblige the general commanding to declare that there is no further occasion to pursue the case.

Keep a copy of your report; you may be called on by the court-martial and have need to remember your arguments. Your evidence in court should be entirely verbal, and you should not use notes.

III.—CRIMES

To avoid endless repetitions, only a few examples of those military offences with regard to which the question of responsibility arises can be given, as well as some of the more common types of insane criminals. It need scarcely be said that these examples are only indications; and that, apart from them, all manner of occurrences are possible.

§ 1. Running away; Abandoning One's Post; and Desertion

These are three offences which it is not juridical to join together, and yet which it would, from the standpoint of mental responsibility, be unreasonable to study separately. It is their duration and the circumstances in which they occur that distinguish them, much more than medical reasons, when the latter do intervene. Besides, in troops in the field, these offences are practically equivalent.

Running away, as Régis has clearly demonstrated, is the most constant element of military crimes. It is the most common, the most simple, and the one in which all the rest end. It is also the natural reaction

both of those who are guilty and of those who are ill. Even in peace-time, the privation of liberty is what weighs most heavily in the regiment. In war-time, circumstances are often evil counsellors, and it is not only fear that I mean: there is alcohol, there is fatigue, there are the remains of shell-shock, there are a thousand and one circumstances of life at the front, which we have already seen lead to a state of depression; and there is also the prolonged effort, and the duration of the abnormal mode of life.

So, in every affair of this kind, the first care of the expert should be to reconstitute as exactly as possible the state of the patient at the time at which the offence was committed, to take into account his physical health, as well as the moral circumstances and any episodes of war which may have intervened. It is also the duty of the regimental doctor, if sufficient leisure is allowed him, to make personal inquiries among the comrades of the accused man. By proceeding in this way it may be possible to separate the wheat from the tares: to identify and punish the conscious offender as severely as may be necessary to serve as a warning; and on the other hand, to recognize the pathological motive of those who are really ill. And thus we shall find that of those who run away not so many are guilty as are excusable, at least to some extent. We should also pay great attention to the way in which the flight ended, how long it lasted, and the amount of ground covered by it. One remark: there are cases of running away which, medically speaking, are unconscious, but of which the penal responsibilty is complete: they are those of *drunkenness*, which under military law is never regarded as an excuse.

There are cases in which the total lack of responsibility in the patient is evident, and would be, no matter what criminal act he might commit. These are the *general paralytic* cases, who start off under the impulse of some insane and absurd idea, which they will often have completely forgotten by the time they

are arrested. If the symptoms of the disease are not as yet very distinct, this may be puzzling, owing to the offender not furnishing any pathological motive. It is the same with *organic dementia, chronic alcoholism with marked intellectual impairment, and insane uræmic* cases. These types are, as a rule, of a more advanced average age than are most of the troops at the front. Among cases of running away from the rear they are not infrequently met with.

A man in a state of *acute mental confusion* is, as I have pointed out before, very likely to run away by reason of the automatism which dominates him. Note that such cases occur fairly often among the troops at the front, where acute mental confusion results from both toxic and emotional causes. Note also that they are always worse at night, when the delusions and hallucinations increase. It is under such conditions that the abandonment of a post in face of the enemy, or disappearances which are taken as meaning a voluntary surrender, occur. Three men sent back from Germany came to me in an undoubted state of chronic mental confusion, and of whom the psychiatrical observation dated almost from the day of their capture, for they had been immediately put into an asylum. The three cases were alike: the men were tired out, emotional, predisposed, and with an alcoholic tendency. In the one case when on patrol, in the other two cases when on sentinel duty, they had gone off at haphazard and had been taken by the enemy. As regards one, the pathological character of his flight had already been established through the evidence of his comrades, and there were no after-consequences. As regards the other two, they had been condemned to death as defaulters, their names had been posted up at the town-hall of their dwelling-place, and their families struck off the list of dependants receiving an allowance.

Mental confusion does not always last as long as the flight itself; or, at the very least, when the man is found again he may be sufficiently recovered to make his story seem very suspicious. The irresponsibility, which

may really be complete, requires in such a case great care in establishing it. Generally it rests upon rather short fits of delusional confusion, lasting only a few hours or a few days.

The *chronic delusions of persecutory mania* sometimes lead to running away, either under the influence of urgent hallucinations, or by reason of the increasing insanity, fed by fabrications, delusions, and hallucinations. The diagnosis is always difficult, for those of the insane who are still in the army are evidently men in whom the disease has not yet exteriorized itself, if I may put it that way. They have created a chimæra, and as, in their quality of persecutory maniacs they are reticent, the difficulty may become extreme. Add to that the mysterious mien, the air of importance which the patients assume, the letting slip of "telepathic communication" or "wireless telegraphy"; sometimes no more than this is needed to create a suspicion of espionage. But on interrogating the patients we sometimes obtain characteristic answers. "Why do you ask me that? You know it quite well!" or "I can quite see what you are after."

It is also very difficult to recognize the morbid character of runnings away due to *acute persecutory mania*, to those depressive conditions, complicated by hallucinations and delusions, the importance of which I have already pointed out in the chapter on depressive states. These patients have little to say when they are questioned, and they are sometimes very perplexed when they try to recall what influenced them to run away. In a recent article of Mallet's (*Ann. Med. psych.*, juillet, 1917, p. 330) there is an interesting psychological study of these cases of running away, which remarkably confirms observations I have published. He shows that it occurs, not in degenerates or the feeble-minded, but in men who, after a period of incubation, have had hallucinations and persecutory mania. Hallucinations of hearing may be very distinct, voices may be plainly heard, or, on the contrary, it is only the thought which is definite, under the form of

an imperative obsession: 'In my head it seemed as if some one said to me: "Go down there and then you will see them" [his brothers]. 'Was it a voice?' 'Yes.' 'The voice of some one?' 'No.' 'You heard it with your ears?' 'No, in my head.'

It is not till a more advanced period of the mania, after several days, or even oftener after several weeks, that the hallucination of hearing clearly manifests itself. In the early stages it is these impressions "in the head" that it is necessary to try to find out, for they considerably influence the conduct.

These delusional cases are akin to those of *melancholia*. This latter has led to a certain number of runnings away, especially when it takes the form of delusions of anxiety. It probably then leads to a sudden, even desperate, flight in a fit of madness, the man believing himself to be condemned, menaced with execution and tortures. But the melancholic is more often passive, and it is because of offences due to inertia, an apparent unwillingness, that we find him charged before a court-martial.

Mental Debility leads to flight in many different ways, but less frequently than one would imagine, since the feeble-minded is docile. His gregarious proclivity keeps him in his unit, as a sheep in the flock. But he is also more easily influenced than are others, and sometimes falls a victim to the ascendancy of a perverse offender. Sometimes two men run away together, and of the two one is likely to be feeble-minded, especially if it is he who possesses money. The man who wishes to desert teaches him his lesson, arranging matters so as to make it seem as if it were he himself who is influenced by the other; then after the event he robs and abandons his victim.

When a feeble-minded man goes off alone, it is generally in consequence of some suggestion, consciously or unconsciously made, on the part of a comrade. He starts at random, but as a rule not towards the side at which fighting is going on, and it is that which differentiates his case from cases of acute

dementia and confusion. Preferentially he makes off in the direction of the last cantonment he was in before going up to the trenches—that is, if he happens to be in the front line at the time he runs away. Or else, which is more common, if he decamps from a rest billet, he is found wandering in the neighbourhood of the cantonment, often decidedly perplexed at the situation in which he finds himself.

When a mystical or prophetic delusion is added to the mental debility, then the case becomes more simple from the medico-legal standpoint. In the beginning of the war we came across men who believed themselves to be inspired with a pacificatory mission, and who wrote letters to the commanders-in-chief and to the Governments. The lunatic asylums soon gathered in those particular customers, and we have seen no others of their type since.

Epileptics often give rise to medico-legal problems of the utmost importance, which are nearly always difficult to solve. As a matter of fact, they may suddenly display the most complete irresponsibility at a given moment, though hitherto there may have been no reason to suspect their condition. On the other hand they are quite normal between their attacks; and finally, as I have pointed out before, they may have conscious impulsions and complete lucidity, though they are nevertheless under a pathological influence.

As concerns those epileptics who run away while totally unconscious, owing to ambulatory automatism, the flight of the individual who finds himself, he knows not how, far away from the place he started from, one point nowadays is well established, which is that the complete loss of consciousness is short, and never lasts longer than a few hours. Epilepsy may thus be suspected, and especially looked for, after the occurrence of some short absence, such as the abandonment of a post, rather than desertion properly so called. If there were witnesses of the running away, its epileptic nature may be deduced from its suddenness, the man having

started off running straight before him, paying no attention to calls, and showing signs of violence toward those who tried to stop him. It is the well-known *procursive epilepsy*. It should be added that this is very rare. In reality the diagnosis is chiefly established by the record of authentic fits during the period of training. The difficulty is that so many epileptics scarcely ever have any but nocturnal fits, so that their comrades remain unaware of them. An epileptic seen by Verger, one who had abandoned his post when on double sentry duty, had only nocturnal fits, of which he became aware solely by finding that he had wetted his trousers. Like many others he had tried to conceal this infirmity as far as possible. With some epileptics running away is an habitual, or at any rate a frequent, substitute for a fit.

True ambulatory automatism, that by means of which people have found themselves one fine day at Bombay or New York without being able to understand how they got there, is *hysteria*, and this running away is one of the reasons why hysteria, the manifestations of which relate to the nervous system rather than to the mental condition, finds its place in these observations. There have certainly been some flights of this kind since the war began, as there have also been other serious hysterical occurrences, such as lethargy, paralysis, etc. But nothing seems to have been published concerning them, which is perhaps just as well, considering the suggestive influence of these cases. Besides, it must be admitted there that are no monosymptomatic cases of hysteria specially limited to phenomena of this kind, and there is not much risk of mistaken diagnosis. When the running away shows signs of having been of an hysterical type, examination and records will establish the diagnosis.

Up to now, we have considered those cases in which the offender was insane within the meaning of the penal code, that is to say, he was incapable of appreciating either his action or what the results of that action might be, which practically means that he was

totally irresponsible. But instances are much more numerous in which the flight has a pathological character, though the question of responsibility is contestable, or at the very least needs to be determined and proved.

The *unbalanced* person runs away on the slightest occasion. I have pointed out his instability, his habitual unruliness, the impossibility of adapting him to his environment in any lasting way. In peace-time, it is his incessant propensity for absconding that leads him to the disciplinary quarters. In war-time, the possible consequences of his action are no check on him. He runs off, either through some sudden unreasonable impulsion, or after a period of several days during which he is restless and seems worried, *il à le cafard*. Then the obsession wins the day, and he starts off. He understands quite well what he is doing, but he cannot help himself. Sometimes a sexual attraction is mingled with the vagrant impulse—with the "dromomania"—but it serves chiefly as an occasion. The tendency is chronic and incurable. Very often it dates from childhood, and we should bear in mind the advice given by Régis with respect to such cases, which is to make inquiries concerning their school life, when we shall discover that they were inveterate truants. These men, in whom the habit of running away is only one of the manifestations of their habitual impulsiveness, are particularly defenceless before it. In peace-time, with its longer delay before a man is posted up as a deserter, the authorities may sometimes overlook very short illegal absences: in war-time that is impossible. In dealing with a case which is clearly of this kind, and in which the bolts take place independently of an avoidable alcoholic element, or of an interested motive, there is nothing for it but to conclude that it is a case of total irresponsibility, and advise an acquittal.

I have just referred to the alcoholic element. There are *incomplete and prolonged states of drunkenness*, which are twilight conditions, intermediate between acute drunkenness and mental confusion, the first of

these not involving irresponsibility, but the second means positive mental disorder. It depends upon the particular case. With regard to young improvable patients, utilizable in the army, it is best to infer drunkenness, and allow of conviction along with a reprieve from the front. As regards the old alcoholic, an auxiliary at the rear, a worker in a war factory, who runs off one fine day " because the melinite was poisoning him," when really it hardly did more than make him feel thirsty, we may be more lenient; all the more so because, the kidneys and liver being affected, the element of mental confusion is undeniably more pronounced.

The *shell-shocked,* and those who have received *cranial wounds*, sometimes run away after a fashion it is more difficult to define. Leaving aside those that are due to a fit of true mental confusion, of masked epilepsy, alcoholism, or an hysterical manifestation, all of which fit into the preceding categories, there still seem to be some which are due to a kind of lack of will power, to a psychic state, to passivity. This state may be caused by the fact that, knowing they are unfit for the front, and feeling as if they had done their " bit," these men are less amenable to discipline; but it may also be kept up by the headache and the apathetic despondency which are so noticeable in many of them. The problem will always be difficult, and only to be settled by a most minutely detailed examination.

There are *psychasthenic hesitators*, who have never been wounded. Unlikely as it may seem, there are indeed some who become deserters simply through this aboulia. It should at once be added that then there is hereditary and serious derangement, and that only their wealth, or the good position of their family, which had hitherto preserved them from all the trials of existence, has saved its victims from falling into the hands of the law before. Here is an example: X—— is a man of thirty-nine, in the auxiliary service because of his bad general condition (former pleurisy).

He has a flourishing business, but its prosperity is entirely due to his parents and his partners. He himself is incorrigibly idle, by reason of indecision, slowness, negligence, and lack of energy. He never got up before midday, and his civil life was hampered by this perpetual infirmity, which had long caused him to be looked on as eccentric, had prevented him from marrying, and had made him miss many good business opportunities. Mobilized in an auxiliary service at the rear, his duties were changed several times, doubtless by request of his chiefs, who found their authority wasted on him. One day he was chosen for a post in a place he had lived in before, and of which he considered the climate too severe. As luck would have it, on his way to join up at this new post he had to pass through the town in which he used to live. The delays on the journey were sufficiently elastic to allow of his stopping there. But when once he found himself in his own home he could not make up his mind to go away again. For eight days he went on making up his mind to take the next train, but remained where he was, until at last his family, worried about this prolonged leave, which he was unable to justify, put him into the train that took him to his destination.

It is certain that these "negative" abscondings are not solely pathological, and that the character of the individuals themselves, their selfishness, and their dread of exerting themselves in the slightest degree, are the true causes of their delinquency. An energetic education and a wisely exercised authority might have averted mishaps of this kind. But nevertheless they are not guilty actions comparable to that of the man who deliberately and of set purpose grants himself an unpermitted leave.

The person whose case we are discussing fought against temptation as the days of delay slipped by and he glided with them towards desertion. He fully understood the position, and in consequence experienced an additional anxiety, which made it more difficult than ever for him to make up his mind. But

he had a frantic dread of the climate in which he had formerly suffered from the cold. He was afraid of a court-martial, afraid of a tubercular relapse or pneumonia, and unlike the donkey between two bundles of hay, he remained hesitating, not between two pleasures but between two evils.

Cowardice; Morbid Emotion.—Those abnormal persons who cannot make up their minds, or *a fortiori* cannot be resolute, are hardly in their place in these present days. Still less so are the cowards. But as regards these we must come to an understanding. We do not in any way palliate acts of cowardice, but we must take into account certain states in which men literally are not masters of themselves, and are consequently unamenable to any authority. These cases are of a pathological kind. Invariably, in all those I have come across, or of which particulars have been published, either a decided hereditary or acquired mental deficiency (chronic alcoholism, former syphilis with cerebral enfeeblement) or some casuality of war, (wound or shell-shock) has been discovered. Thus in this last event it would only be that acquired exaggeration of the general emotional instability that I have already referred to as existing among the former wounded and shell-shocked. I copy here a characteristic observation made by Logre :—

The patient, son of an insane father, had from his childhood been of an anxious, fearful temperament. He had night terrors. He was possessed by a dread of illness and death. As he neared adolescence he displayed agoraphobia, and when he was out alone in the streets he had to ask the assistance of a policeman or a passer-by when he wished to cross one of the public squares. He exhibited some obsessions, suicidal or homicidal, and periods of agonized psycho-neurosis, with sensations as of imminent death, unreasoned terror, need of a change of place, and bolting.

Life at the front was bound to put his emotional instability to a cruel test. In the trenches he was known to all as a "funk." He was terribly afraid of the big guns.

He started, turned pale, and trembled; complained of palpitation, dizziness, a ball in the throat, and a pressure on the epigastrium; he whined and lamented. He became the laughing-stock of his comrades. "But really and truly," he said to us, "I was much more afraid of my own feelings than of the shells. That is what my comrades could not understand." For a time he was employed as cook, in a less exposed position. But on being again sent back to the trenches he could stand it no longer; with the complicity of a more resolute comrade, whose decision encouraged his indecision to take action, he fled, thus presenting that interesting problem of the double flight, of the collective running away. This was the case of a highly emotional and also unscrupulous man being dominated by a vicious one. We decided that it was a case of limited responsibility. He was condemned to two years of prison. But after the sentence the authorities gave him a chance of rehabilitating himself by sending him back to the trenches. He had to be evacuated several weeks later on, owing to his increasing emotional instability. (*Revue neurologique*, 1916, No. 7, 11, p. 20.)

That was a case of hereditary weakness: here is another in which the initial weakness was increased by shock; it figures in a very interesting communication from Pactet and Bonhomme. ("Société médico-psychologique," 26 mars, 1917, in *Ann. Med. psych.*, juillet, 1917, p. 375.)

He had already been in prison for a fortnight before the war, after having been in the army for five months, because of a delay of three days in returning after a convalescent leave. His leave ended during the Easter holidays, and he thought he could very well remain three days longer without being severely punished. At the beginning of the campaign he behaved very well. In March, 1915, he received a double cerebral shock through being torpedoed. After that his character changed. Previously he had been almost indifferent to danger; afterwards he could no longer dominate the dread which possessed him every

time he was called on to return to the trenches; and he felt himself irresistibly compelled to flee in the opposite direction. Accordingly, there was a first condemnation to five years of prison. Sent back to the front, he ran away again. This time his captain only asked him to redeem himself by his exemplary conduct. But a few weeks later on he ran away a third time.

I myself had in my hospital a man of forty, given, before the war, to excessive drinking to such a degree that he had to wind up his business, which he was no longer capable of managing. He was a good soldier at the beginning of the war, as was proved by his army record. On a certain day he was somewhat seriously shell-shocked. When he was sent back to the front after that he was not afraid of bullets, but he could not stand the explosion of the enemy's shells, or the report of our guns. On a day of bombardment he ran away. Because of his good antecedents he was sentenced only to three months' imprisonment with a reprieve. But shortly afterwards the same thing happened again. Called before a court-martial, he was sentenced again, after an examination at the Lyons Centre, which led me to decide that there was a relative responsibility, although I pointed out that for several months at the least there would be a risk of a renewal of the offence if the formerly shell-shocked man were allowed to remain in the zone of artillery explosions. Owing to this report, and after his return to the front, he was called before the invaliding tribunal of B——, which paid no attention to it and kept him in the combatant ranks. Directly after his return to the front line in a bombarded sector, he ran away again, and was finally placed in an army neuro-psychiatric centre.

Following on the communication from Pactet and Bonhomme, a discussion took place, which confirmed the existence of these cases, in which a pathological fear, limited as a rule to the effects of artillery, has only appeared after some accident, the military career of the patient having been normal up to then.

Laignel-Lavastine likewise has proved the existence of cases of this kind among the feeble-minded.

For the rest, pathological cowardice manifests itself not alone by running away. There is nothing more instructive than that other observation made by Logre (*Presse médicale*, 9 juillet, 1917, p. 395) which I have already quoted, concerning the tabetic general paralytic who had fits of extreme emotion with in continence of urine whenever he heard the whistling of a shell. In his case the physical manifestations of fear were caused by emotion, but had an organic origin.

§ 2. Defaulters

What I said about simple absentees, and of the pathological characteristics they frequently present, is applicable to many actual defaulters. Of these it may be said that there are two distinct classes. There is the defaulter who is voluntarily a traitor to the common obligation, who hides himself, leaves his own part of the country and takes a false name; and there is the unconscious defaulter, who is in one way or another mentally deficient. He does not hide himself, is not at all pre-occupied with his position, and goes on living just as usual.

There are, however, among those defaulters who remain at home, some who do understand their military status, but who, in pursuance of some insane idea, have resolved to pay no attention to it. I am acquainted with the story of a magistrate who had had, some ten years ago, a most severe attack of acute mental confusion, which had left him slightly impaired mentally, but not so much so as to interfere with his carrying on his profession. After war broke out, he was mobilized, and shortly after had a fresh attack of mental confusion. He was interned and temporarily invalided. By the end of his year of invalid leave he had resumed his judicial functions, when he was called on to appear before a military exemption tribunal.

He refused to do so, adducing the most absurd, but evidently sincere, legal arguments why he should not be submitted to examination, and manifesting at the same time characteristic grandiose ideas. As a matter of fact, this magistrate—whom the authorities hastened to discharge completely—is a case of slowly developing and paroxysmal premature dementia, which at the present time is tending towards paranoia.

I have likewise seen a case of this kind in a peasant with persecutory mania. The police are naturally inclined to report the conduct of these persecutory cases as being due to refractoriness or unwillingness, since, on their being investigated, the men are said to be in full possession of all their faculties. We, however, should be very careful to remember that the defaulter who does not hide himself may possibly be mentally disordered.

There are defaulters of a special kind who are judicially declared to be deserters, but who are psychologically defaulters in the sense that they did not fraudulently and illegally throw over their military duties, but that they simply outstayed their leave, remaining at home after it had expired. Here, for instance, is the case of a shell-shocked man who had also been wounded and considerably impaired mentally. He was over forty-five and a former drunkard. After the shell-shock, and following on lengthy and repeated sojourns in hospital, he was put to do munition work in a shell-loading workshop. One day he was granted an agricultural leave, and finding his land uncultivated, set to and got through an enormous amount of work in the first few days. He was an old bachelor, his only near relation being an elder brother. The love of the soil was his only passion. It recaptured him so thoroughly that after several days, what with fatigue and exertion, and above all the lingering effects of his former cerebral disturbance, he no longer remembered that he was a soldier and that he ought to go back again. He made no attempt to hide himself, but worked from dawn to dark, and when the police- who

had been warned by the brother, anxious at the man's prolonged stay in the country—came to look for him, he could not understand it at all. He thought that as he belonged to one of the older classes, and had been wounded, he was exempt—or rather he no longer knew or wished to know anything about it. He was there at home among his fields and trees again, and nothing else existed for him. He had been an excellent soldier, and there had been no reason to suspect him of any exaggerated tendencies. He did not seem to be mad, but on making inquiries, the police found that his neighbours had thought him odd; and on his being examined, a marked mental impairment was noticeable. But even so, it had to be looked for. Result: discharge No. 1. No ground for prosecution.

Unwillingness

A delinquency in war-time, with the serious consequences it may entail, throws the little delinquencies of peace-time, such as unwillingness, systematic negligence or disobedience as regards some petty detail, quite into the shade. These minor offences are, however, very interesting from the mental point of view. Some of them are certainly pathological cases, and they are nearly always difficult to elucidate. Some are cases of premature dementia with negativism. Others are like that strange case of melancholia Haury speaks of. On a day of route marching (this was before the war) he refused to leave his room. The Code was read to him with its account of the consequences of refusing to obey, but it made no difference. At the court-martial it was useless to question him: he made no answer, or only replied by "Yes" or "No" without explaining himself in the least. It was discovered that in the barracks he had already managed to evade drill by hiding himself. In the hospital, where he was put under observation, he remained inert, shunning even the slightest exertion, refusing to raise himself up in bed, and even to take his meals. One day he asked

Haury to examine him, because he was sure he must have heart-disease, since his aunt died of that complaint. This request was a revelation, and led to the recognition of the delusion, which he also confessed to: he did not wish to do anything for fear of increasing the complaint with which he believed he was affected, and the whole of his existence hinged on that fear.

The extraordinary obstinacy of the feeble-minded with respect to such ideas will be remembered.

§ 3. Acts of Violence

I have already pointed out, when speaking of running away, the abnormal characteristics of certain cases of heavy and usually prolonged drunkenness. Doctor-Inspector Simonin and Haury, among others, have described cases of aggressive and violent drunkenness. Excitement and the consumption of absinthe at the beginning of the war made these cases of frequent occurrence until 1915. At present they seem to have somewhat lessened, though strong spirits are not needed to cause them. Drunkenness from any cause may manifest itself by a sudden and alarmingly aggressive temper. The man is drunk, but he can hold himself straight and may even appear to be reasonable. Then suddenly he may attack one of the bystanders, to whom, perhaps, up to that time he may not even have spoken, and instantaneously the idea of murder enters his mind, and he puts it into action. Or he may kill without any preliminary altercation. Without the exchange of even a single word he may set upon some inoffensive passer-by in the street. The next day he will remember nothing of what happened.

It is a sudden furious madness, the most terrible of all, because it is the only one in which the madman "thirsts for blood." And as his strength is increased tenfold through the excitement, there is the greatest difficulty in disarming him. It is nearly always in the predisposed, in hereditary alcoholics, or the sons of

lunatics, that such symptoms occur. An alcoholic element is necessary, but it may be very slight. In reality these cases are intermediate between delirium tremens and epilepsy.

Even without alcohol as a lever, epilepsy alone may cause impulsions of this kind; but they are infinitely less common. If epilepsy is proved and patent, the irresponsibility of the patient is absolute. It is not so when the case is one of drunkenness.

Without going as far as a tragical attack of furious madness, drunkenness may lead the predisposed to make criminal attempts against persons or things; but as in the military code drunkenness is not considered an excuse, its influence need not concern us here.

§ 4. Wilful Incendiarism

Wilful incendiarism also is one of the misdeeds of alcoholics, not of those in a state of continuous confusion, but of those who are under the influence of a temporary drunken excess and the impulsions produced by it.

But it may likewise be the result of *impulsive obsessions* in degenerates or the feeble-minded, or of some passing insane idea in the early stage of primary dementia, for instance. I have seen a curious case of it, repeated after forty-eight hours' interval in the same army quarters, by an educated degenerate, a former neuropathic case, and still exhibiting various disquieting peculiarities, such as strange absences of mind, faults of behaviour, laughing for no reason, and negativism, all of which pointed to a beginning of primary dementia. He was a man of good birth and breeding, and the pathological nature of his actions had been recognized by his comrades themselves, who were struck by the complete lack of motive for them. We succeeded in drawing from him an avowal of the impulsive obsession to which he had twice given way.

§ 5. Secret Communications with the Enemy

In this sad section there is but little to mention save two possible causes of irresponsibility. On the one hand there are those affected with delusions, especially of a mystical type, and who, impelled by their grandiose ideas, make advances to the enemy through the intermediation of some neutral country, advances which they hope may lead to a peace of which they will have been the originators. The insane character of their overtures is not always apparent in their intercepted letters. Once again it must be said that the persecutory maniacs, especially those who put their own construction on everything, are sometimes remarkably lucid, which is puzzling for those who have had little or no experience of them.

On the other hand, it is not uncommon for the enemy's spies to get into communication with slightly feeble-minded men, whom they know to be malleable and suggestionable, and from whom they manage to extract information without the men themselves being fully aware of it.

§ 6. Theft

There are well-marked morbid thefts, such as those typical ones committed during the opening stage of general paralysis (medico-legal period). With some variations they are common to all demential states. They are characterized by their absurdity, their lack of substantial advantage, and the absence of precaution. They may really be unconscious acts, especially in the case of a general paralytic, who may take some article or another from a shop counter, and carry it off without knowing what he is doing. But it may, on the contrary, be a completely conscious act resulting from a passing obliteration of the moral or critical sense. In that case its nature is more difficult to determine. Here is an example taken from my practice.

A man of good family and reputation, a manufacturer who had, as inquiry proved, several hundred thousand

francs' worth of goods in his warehouse, had been wounded and shell-shocked, passed into the auxiliary service, and assigned to an artillery park in the same town as that in which his business was carried on. One day he was ordered to take his motor lorry and make a delivery of goods in an out-of-the-way spot where a quantity of waste scraps of copper were lying about. He finished his job, and then, being alone and unnoticed, he gathered together about 200 kilogrammes of copper and carried it off in the lorry to his own warehouse. There he suddenly realized what he had done, and was distractedly preparing to take the copper back to the place he had brought it from, when the police came to arrest him. A neighbour who had witnessed his arrival with the copper in an army motor lorry had immediately denounced him, thereby not allowing the culprit sufficient time to return what he had taken; but it was proved that he had fully intended to do so. Inquiry brought out the facts that he had had syphilis eighteen years before, also malaria, that he was a moderate but steady drinker, and that there were numerous and old-established eccentricities of character and lapses of memory; also that there had been a hemiplegic crisis six months before the delinquency, and a most distinct shell-shock a year before it. I concluded that it was a case of general paralysis in the first stage, with symptoms somewhat analogous to an amnesic crisis.

I have given this instance in some detail, so as to show the difficulties there may be in certain cases. But as regards thefts, we should not, in my opinion, be too ready to extend the domain of irresponsibility. The study of Juquelier and Vinchon's book, entitled *The Limitations of Morbid Theft*, as also the daily experience of medical experts, should enable us to realize this. Apart from cases of dementia, and those of some maniacs or hypomaniacs, the thieves are not really irresponsible; and if there is a pathological element, it is likely to be that lack of mental balance in degenerates which yet leaves them entirely conscious of their acts.

Though it may be readily enough admitted that it is difficult for them to resist the impulsion to run away, it is not the same with theft. Besides, the thefts of the unbalanced are generally of a utilitarian type, and that is of great value towards deciding the question of responsibility.

§ 7. Swindling; Illegal Wearing of Chevrons and Decorations; Usurpation of Functions

It is certainly artificial to class these different delinquencies together, but we are here concerned with medical experts' reports, and not with criminology. The men who commit these diverse offences are all of the same stamp, whether their health is good or bad, and such charges as those above are often accumulated in their dossiers. Each one of these acts is a fraud which necessitated reflection, deliberation, and premeditation. This means that, except for certain cases of illegally wearing badges and decorations, these delinquencies are conscious acts from their first inception, and that their authors are fully responsible in by far the greater number of cases.

These culprits are swindlers of more or less skill and self-assurance; they are men lacking in moral sense, who take a base advantage of circumstances and of the trust inspired by a war medal, or an aviator's insignia, to increase the number of their dupes.

I am well aware that among them there is a certain number of unbalanced persons. I have examined a series of cases of that kind, and found that they were bad characters, but not irresponsibles. Sometimes they were habitual offenders, who arrived with reports of former medico-legal examinations which had terminated in a verdict of no true bill. They evinced in turn mythomania, mental debility with grandiose ideas, habitual intoxication with opium or cocaine, a recent syphilis, etc. However, not one of them deceived himself, or could be looked on as *bona fide*. The unbalanced state caused by such tendencies, habits,

or diseases could not be *a priori* excusable, and does not necessarily lead to wrong-doing. This last retains its importance even when the man has made himself remarkable by eccentricities calculated to create the belief that he is mentally disordered. Neither is the fact of the offences being repeated after the infliction of a penalty, and the consequent ineffectiveness of the latter, a valid argument to prove the culprit's irresponsibility. At best he can only be looked on as one of those unbalanced detrimentals whose place, in default of a special institution, is in a military prison, not in a lunatic asylum, as he always manages to escape from there. The army psychiatrical experts, whose task with reference to offences against discipline is so difficult, would discredit themselves if they exculpated these scamps.

I made an exception of certain cases of the illegal wearing of badges or decorations. There are two very different possibilities. One may be that a private soldier, generally after an attack has taken place, suddenly sports the stripes of a corporal, and is prosecuted because he is not entitled to do so. As a rule it is a case of a feeble-minded man who has received a word of encouragement or praise from an officer since dead, and is under the impression that he has been regularly promoted. The courts-martial are apt to be very severe in a case of this kind, clinging too closely to the letter of the regulations, charging the poor fellow with swindling because of the difference between a private's pay and that of a corporal, which he may have drawn for a few days.

The other possibility is quite different. The offenders may be seriously feeble-minded who are really insane, or cases of dementia, especially those of general paralysis, who, like the patients in lunatic asylums, have a fancy for wearing decorations they have no right to, but who have no end in view, and no wish to profit by doing so. They are widely different from the offenders just spoken of, and a cursory examination suffices to enable us to realize their irresponsibility.

IV.—SOME TYPICAL CASES

Besides the preceding indications of a general kind, it may be useful to draw attention to the characteristics of some of these patients, seeing that this book is especially addressed to those medical men who have not had any specialized experience; the professional psychiatrists will be good enough to excuse this, for them, unnecessary dissertation.

§ 1. The Protesters

It is not always as the accused that insane persons appear before the courts-martial. They sometimes figure in them, or at the War Office, as the accusers or the plaintiffs. Such persons are affected with persecutory mania, leading to insane interpretations and delusional claims founded on some initial error, over which the patient's peculiar temperament has built up a complete fabric of delusion.

These claimants are occasionally inventors, who importune the authorities with their petitions and overtures. More frequently they are persons, officers particularly, who believe they are the victims of the injustice or animosity of one of their chiefs. Little by little their protests grow stronger, till discipline is forgotten and a penalty is incurred. This more than ever excites the spirit of protest, which runs riot unchecked. Whether punished, condemned, or looked on as the victims of mental disorder, they behave in the same way: there are letters, applications, petitions, protests, and finally dangerous aggressions. So be very cautious with regard to those patients who are under observation because of their excessive claims or protests. Do not hesitate to take any necessary measures concerning them; and if you can possibly manage it, do not permit these precautions to be put off till the patient has been transferred to a special administration centre. Moreover, say nothing before

him which might serve to strengthen his delusions against any one of those whom he believes to be his persecutors. These patients are remarkably lucid. The basis of their argument is erroneous, but apart from that it holds together remarkably well. If we do not go back to its originating cause, we may well believe that we are confronted with a person who has really been victimized. It would be an unparalleled imprudence to allow this impression to become visible, for later on you will be obliged to beat a retreat, and the patient would deduce from it that you, too, in your turn, had been won over by his persecutors.

§ 2. The Self-accusers

One day a soldier appears before one of his officers, and in a matter-of-course way says to him: "Just look here. I went out for a walk with X. an hour ago; we had had enough of it and decided to go back. Then he changed his mind and wouldn't come, and we quarrelled; and then I killed him." Another man will say that he was on sentry duty when a Boche came along and they had a chat, and he gave the Boche information, and now he wishes he had not done so, and is repentant.

Try the experiment on hearers who have not been warned beforehand, and you will find that such self-accusations always take them in; and more especially is this the case in so eminently suggestible an environment as is that of the army, in which sincerity lends so much weight to the spoken word. According to the degree of experience or caution of those who receive these confidences, they will be more or less deceived. Some do say, "We must find out if it is true," but many accept the truth of the revelations without a doubt. If the man said to have been killed turns up promptly, the self-accuser is taken for a practical joker, and treated as such. But if it should so happen that the supposed murdered man goes off on leave just at that time? Or if the incident occurs the day

after a battle, and there are missing men, he among them?

In Paris, the police are accustomed to such avowals. When a man comes and tells them he has cut his wife to pieces, it is much the same thing to them as if he came and told them he is Napoleon VI. They just reply, "Oh, all right! Jump into this carriage and come along with us," and drive off with him to the special infirmary of the police station. But to be able to take things like that it is necessary to become used to them, and that is only too easy wherever men drink much, as they do in Paris and other large towns. For these self-accused culprits are simply drunkards, and some hours after their confession they will not even remember having made it; but that will not mean the end of their troubles if their confidences were made to the wrong person.

There are still others whose confessions are difficult to appreciate properly. They are the short-sighted melancholics, whose expression is furtive, and who really do look extremely guilty. If they only accuse themselves of some trifling peccadillo, or of some quite impossible offence, all very well; but they may accuse themselves of having had secret communications with the enemy, or of having caused the death of such a one among their comrades, or, above all, they may be indefinite, and that is most dangerous. The drunkard spoken of, who is the sport of an hallucination, makes a precise accusation against himself — he will give alarming details concerning his crime; but these, when an attempt is made to verify them effectually, prove the falsity of his confession. The melancholic says little, and that little is not a detailed statement—it would puzzle him to make one. His delusion is one of general anxiety and remorse. It is only as an accessory that he believes he has committed a crime. When questioned, he knows nothing, but simply bewails himself, seeming to regret both his crime and having confessed to it, thereby playing the part of a criminal better than ever.

§ 3. Those who Confess Too Easily

Haury has clearly defined the characteristics of certain patients, who are unduly apathetic, slow, idle and negligent, passive, but complete types of bad soldiers, and who one fine day are called up for examination, either because they have committed some misdeed, such as running away, or because they are suspected of a certain offence, the author of which is unknown. An attentive observer will notice that they answer only by " Yes " or " No," but that if they are asked a direct question they seem lost and bewildered, and are always inert. Really the answers they give are to leading questions: " You went to such and such a place? " " Yes." " You had an accomplice? " " Yes." " It was so and so? " " Yes." Such statements look very well in an official report of the inquiry, but if some other person questions the same man directly afterwards, making other suggestions, and consequently leading him differently, absolutely contradictory admissions will be drawn from him.

These men are feeble-minded, and on the way to primary dementia. Their chronic apathy verges on stupor, or at the very least approximates to that extreme detachment from things in general which betrays the mental decline due to certain forms of primary dementia. If they run away, they are in a state of confusion, or, to be more exact, of cerebral arrest. They do not know what they did. Though still presentable, they are as stupefied as any habitual heavy drinker. And like him, they readily accept any suggestion made to them, sometimes simply confirming it by " Yes " or " No," sometimes by echoing the question put to them. Examiners, beware of the men whose avowals seem to do so much honour to your perspicacity!

§ 4. Those who seem to be Making Fun of You

Do not lose your temper with those who seem to be making game of you. You would lose all power over them, and it is absolutely necessary that you should find out if they are ill-natured rogues, or cases of primary dementia whose sudden slightly explosive laugh is an early and valuable symptom, or merely eternally smiling, feeble-minded simpletons. Oh! that exasperating smile of the feeble-minded person! Like that persistent, exaggerated or unjustified complaint of his concerning some unimportant infirmity or ailment, it is a manifestation of the pauper spirit which characterizes his type.

Certain persecutory maniacs smile also—a strange smile, full of mystery—when they come across some new detail that helps to confirm their insane conviction, so that they gain another "proof" of it. It is the satisfied smile of the man whom events have shown to be in the right, and it is likewise the superior smile of the person who flatters himself he cannot be imposed upon. Or it may be the smile, mocking indeed, but also hostile, of the reticent persecutory maniac who sees you are trying to find out the secret he is determined not to tell.

§ 5. Those who have "Le Cafard"

Do not be too moved to pity by those gay old boys, or those colonial natives, who tell you that if they have run riot or gone on the booze it was because they had "le cafard," and that when that gets hold of them nothing makes any difference until it has gone away again. "Le cafard" has a broad back! Army doctors who had given close and prolonged study to the subject before the war have described the part played by alcohol in this state of obsession and impulse. In predisposed cases it is possible that this element is of less importance, but it is certainly far and away

the chief cause both of the disordered condition and of the impulsive action.

§ 6. Those who Break Out of Bounds

We have already discussed the question of those who run away, as also that of the unruly unbalanced cases. But among the patients included in this double category there are some who really take an undue advantage. There are some whom no amount of discipline can keep in confinement: they escape from any place to which they are sent to be kept under observation, from all disciplinary quarters, and all restraint; and this simply through an untamed, instinctive desire for freedom, for neither dipsomaniacal tendency nor sexual appetency are factors in the matter. These men, for the very reason that they have not been damaged by alcohol, may make excellent soldiers, especially as attack troops when a bold push is to be made. They constitute the best element among the unruly.

There is a certain number of them among the men of the Foreign Legion, and also among those condemned by default as deserters, but who returned to France at the time of general mobilization. I have seen some whose regimental record bore a whole series of desertions and insubordinations, but apart from these there was nothing to take exception against. We shall meet with them again in connection with the question of discharge. It is not always easy to know what decision to come to in such cases.

Of course these men are in an infinitesimal minority among those who break out of bounds. But in their case the action is symbolic, as it were. It, and it alone, constitutes the whole of their offence and all their pathological condition; and whatever we may do, it will surely be repeated. It is just this which distinguishes them from the thoroughly worthless characters.

§ 7. Those who Dare not Return

Among those who took an unlicensed leave there are a fair number who remain away merely because they do not dare to return after having been posted as deserters. The same sort of thing may be seen among children who play truant from school; and how should it not be found among these men, whose stolen moments of liberty may cost them so dear?

And, indeed, they are nothing but grown-up children, feeble-minded, easily suggestionized, lacking decision and will power, so that they are easily led away by a comrade or the attraction of a desire. So off they go, telling themselves that they can quite well take a little holiday, and that they will come back in time enough for the consequences not to be serious, and that they won't be punished, or only just a little. Circumstances proved to be stronger than themselves, and they were caught. Rebierre devoted a good study to them before the war, called *The Timid Delinquent.*

Most certainly the fact of having stayed away so long should not be looked on as an excuse; but when it is proved that the culprit was afraid to come back, it is an indication respecting his mental condition, and as to the possibility of finding an explanation of his behaviour in it. This peculiar timidity is sometimes shown up by events. Certain of these culprits who had had a quite tolerable post in the army, one free from danger, such as those of the older men in the Auxiliary Services for instance, had led a perfectly miserable existence after they had run away. If they had chosen, they might have returned to their usual life; but they were afraid to, dreading even more than the penalties incurred the moment of giving themselves up.

Some have even been seen loitering about in the neighbourhood of the barracks, in the hope that some one would come to arrest them, and so save them the trouble of making up their minds.

When matters have come to this pass, it is certain

we are not dealing with perfectly normal people. They, along with many others, are the big babies of the enormous army family, in which it is so difficult to reconcile a more than ever necessary discipline with individualization of penalties, and with a certain flexibility in the methods of repression.

From this medico-legal point of view, which is to be considered well before the examination at the court-martial, right at the very beginning of the inquiries among the regimental company, a well-informed medical man can be of great assistance to the commanding officers. He only can give the medical reasons why some men should be encouraged, others punished, others kept under constant surveillance, while others should be eliminated as quickly as possible, because in the army, as in the family, example is a most potent and influential guide.

CHAPTER V

MILITARY DISPOSITIONS

Patients suffering from mental disorders should be treated in special institutions, and, as far as possible, by a staff familiar with their condition. After treatment, a series of measures, either provisional or final, may be necessary.

I.—TREATMENT IN SPECIAL INSTITUTIONS

Special attention should be paid to the organization of the institutions, the admissions and the discharges.

§ 1. Organization of the Institutions—General Discipline

In the Army zone these institutions are generally neuro-psychiatrical centres, while at the rear they are divided into neurological centres and psychiatrical centres. This initial combination and this subsequent separation are very sensible, for the sorting out and classifying of patients affected with mental disorders should be made by a series of successive stages, the final results of which are to bring each patient into the institution best fitted to receive him, and to prevent an over-hasty placing of those suffering from acute forms of mental disease in the same centre as those who are chronically insane.

Throughout this book we have met with very few madmen, but with many cases of transitory, or at any rate recent, mental disorder. Even if these latter seem to be very seriously affected, they should not be

placed straight off among the insane, as often had to be done early in the war. The specialized institution, whether it be in the front zone, at the base, or in the rear, is always a *medical* centre, and should be installed and fitted up as such.

In the front zone, military as well as medical considerations should determine the equipment of the centres, and only general directions can be given; those at the base, which should be arranged so as to receive and treat for several weeks a fairly large number of patients, should be provided with beds—obviously in varying number according to the zone served, but always in sufficient number. It must be possible to isolate a certain number of patients in rooms with only one or two beds. These need not be padded rooms, but there should be plenty of attendants to supervise them and guarantee good service. In a centre at the base—where very assiduous care will be needed by some of the patients, and where there will be many admissions and discharges—to be in a normal condition of good service, one attendant for every four patients and one doctor for every hundred will be necessary. Clinical clerks, one for every hundred patients, will also be needed.

There should be good bathrooms, with hot and cold water laid on. Rest rooms, apart from the dormitories, should be provided, and a space, which should be planted with trees, where the patients can take exercise or rest in the open air. They should not be allowed to go outside the hospital grounds.

The centres behind the Army zone are generally situated in a town in which there is a Faculté de Médecine, as well as an Army headquarters, and should be well provided with all the various medical appliances. Each centre has been fitted up according to present needs and future possibilities. It has been necessary to bow to circumstances and accept the limitations of existing buildings to a greater extent than in the Army zone, where it is easier to erect or remove temporary constructions at need. The

organization of the Lyons Centre, a two years' experience of which has led to the realization of both its advantages and its disadvantages, is as follows—

1. *A central administration*, comprising at present 150 beds, within a large complementary hospital in which there are both medical and surgical departments, supplying everything that is needed for diagnosis and treatment, and yet at the same time saving the patients from the annoyance of being placed in an institution devoted entirely to mental cases. All the patients on arriving are received in this central department, where they are sorted out, a minority being kept for treatment, the others being passed on. It consists of a certain number of rooms, each with four beds, an arrangement convenient enough for mental cases, especially where there is an insufficient *personnel*; of some larger rooms, and of dining-halls which can also serve as sitting-rooms; and of bath-rooms. There is a large courtyard for the patients who as a general rule may not go outside the hospital. The department is on the ground floor and the first floor. The windows are barred, and the staircase has an "installation de fortune," so as to make it more difficult for the patients to commit suicide by throwing themselves over it.

2. *Divers annexes*, which comprise: an auxiliary hospital installed in a convent which has a large number of rooms, and which is used for the milder cases, those of psycho-neuroses and officers who are only slightly affected. Other annexes are for the reception of patients who do not require special treatment, but who are not allowed to leave the centre because their discharge is under consideration; others, again, are situated in the country, and to these certain cases of depression, and those of shell-shock and wounds in the head, are sent for treatment under medical supervision; and, finally, there are beds in a lunatic asylum to which those patients are sent who have to be interned. This last part of the administration is composed of the Psychiatrical Clinic of the Faculty, say

200 beds, and of two other pavilions, all in the Departmental Asylum of the Rhone, at Bron. The Lyons administrative centre includes 1020 beds, of which 560 are those of interned lunatics. It is unnecessary to add that if the number of beds at its disposal are insufficient, especially those in the asylum, it is because the hospital admits not only the repatriated prisoners from Germany, but also the insane prisoners from the enemies' armies, who await their repatriation at Lyons.

To render the administrative centre thoroughly effective, it is necessary that each department should be amply provided with appliances, including a bathing establishment, and that the *personnel* should not be too limited.

The question of *personnel* is important. I think it should be settled as follows: in each different department of the administrative centre there should be two classes of military male nurses—a few well-educated ones, chosen, if possible, from among men whose profession has given them a certain degree of psychological experience (teachers, priests, etc.), then a varying number of attendants and helpers. The only thing to ask of the attendants is strict obedience to orders. As for the helpers, they will just do to look after the able-bodied patients who will be required to work. All the important part of observing the patients will fall to the share of attendants of the first class. It is they who should discover those suicidal ideas, so often hidden away by the melancholic. One of them should superintend the searching of the patients when they enter the hospital, and put aside all knives and arms. They should detect the exaggerators and the malingerers, and pay close attention to convulsive fits. One of them should be responsible for the management of the bathing department. The officer-in-charge should be chosen from among them, and he should be possessed of considerable influence over his staff and the patients.

But a purely masculine staff is not enough. Even

with the addition of the voluntary element, whose value is often very great, its activities cannot suffice for every detail. For the patients under treatment, especially those confined to their beds, it is necessary to have women nurses. Sufferers from mental confusion, shell-shock, or wounds in the head, are very susceptible to little attentions. Nothing is better calculated to help them back to a normal life, and to dissipate the emotional element, than a woman's care, given without sentimentality but without negligence. Women are also the naturally designed channels of communication between patients and their families; it is they who can best send news of them, write the first letters, make a wife who is afraid of mental disorder understand just what is wrong and be ready to receive her convalescent husband, and warn her to keep him from drinking, etc.

Trifling details and useless precautions, say you? Most certainly, No. The patients we receive, of whom the majority, as cannot too often be repeated, are just as much victims of the war as the ordinary wounded, are, moreover, in a temporary condition of moral, almost legal, minority. It is the positive duty of the military authorities, whose representative in a hospital is the head of the department, to make sure that they are kept in security and properly superintended. An individual psychotherapy is not possible among so many patients, and it is also better for the maintenance of the doctor's authority that this psychotherapy should devolve on his assistants.

Every one who has had any experience with these patients has recognized the considerable influence, for good or for evil, which the subordinate staff has over them. But the task of these latter is so fatiguing, so difficult, so repulsive sometimes, and so absorbing, that a larger place should be made for a carefully recruited voluntary element, which, after some experience to learn its vocation, will be able to render inestimable service.

There are cases of confusion, from whatever cause, that need to be re-educated as if they were children;

and for this a woman's patience is necessary. It is to my voluntary and professional women nurses that I owe it that my patients are materially so well cared for, with that attention and cleanliness in detail which can never be obtained from a male staff. It is especially to them that I am indebted for considerable moral assistance also in managing my patients, and especially for the complete re-education of some among them.

The *methods of treatment* are those that I have already hastily sketched in when speaking of curable cases: baths are necessary for many of them; and rest in bed, in the most tranquil conditions possible, is also indispensable. There is little need for medicinal treatment.

I have said that *discipline* should be very strict, and not only in order to control those who are excitable. Part of the hospital population is made up of an easily led, sheep-like herd. One bad character, one insubordinate man, may do great harm if we are not careful. At his instigation attempts to escape will be multiplied, and, by means of a general complicity, elaborate devices succeed in introducing drink into the hospital.

Patients from the sorting-out centre must not go into the town. They would be exposed to misunderstandings. The diagnosis may, and even should, be doubtful for the first few days. Those who are well enough should as soon as possible be passed into another department (at Lyons into one of the auxiliary hospitals), from whence they may be permitted to go out; but this is a measure which should not be widely extended, or applied to some of the patients in a department and not to others. In the interests of discipline the rule should be general. In other words, the sorting-out centre should be looked on as a hospital for those suspected of insanity. It is for the head of the department and those associated with him to hit upon details and methods which may make the calm and conscious patients resign themselves to this arrangement, which is the only one compatible with safety.

The patients' *correspondence* should be read from the beginning. Useful hints may often be found in it as to the dispositions of their families, and especially as to their own state of mind. It must be understood that this rule should be applicable only as long as there is need for it, but it is indispensable in the cases of those detained on suspicion.

Visits should not be as freely permitted as in an ordinary hospital; they should be strictly limited as to choice of visitors, frequency, and length.

Books and games are practically useless in the sorting-out centre. We shall speak of them again when on the subject of annexes.

§ 2. Admissions—Out-patients

Nothing much needs to be said about those admissions that take place through the ordinary routine of evacuation. Whether in hospitals at the front or at the rear, they are dictated by circumstances to which the hospitals are bound to conform. It would be prudent, however, always to keep one or two wards to put new arrivals into. For different evident reasons it is better not to disturb patients already under treatment by interspersing among them, because there happen to be vacancies, men straight from the front. Good order and cleanliness will benefit by the latter being submitted to a preliminary preparation.

The greater number of our cases from the rear come to us by way of the out-patients' department of our administrative centre. That department is an indispensable part of its organization, the operation of which has been a useful and valuable asset to the centre. Properly managed, with a reasonable discretion, a consulting room of this kind would be very useful for the *clientèle* of civilian hospitals. Ours has saved us from an over-crowding which would have been inevitable without its filter, in a town with such an agglomeration of wounded men, patients undergoing treatment, large dépôt garrisons, and, finally, a crowd of munition workers under military control.

At the time of each successive enlistment, and the calling-up of each fresh class, it has enabled the medical officers in command at the dépôts to eliminate rapidly from the latter a certain number of feeble-minded or worthless men, and it protects them daily from the responsibilities that they or their associates would incur from the presence of dangerous lunatics. Several times over the out-patient department has prevented the departure of men for the front who would have been an encumbrance or even a danger there, such as officers affected with general paralysis, who made a good enough figure at the regimental dépôt, but who, under new responsibilities, would have broken down in a way which might have led to serious consequences.

§ 3. Outings, Annexes, Occupations, and Work

Patients who enter the central hospital leave it either by way of one of the methods of discharge to be spoken of later on, or by being sent to one of the annexes. As concerns those appropriated to interned patients, we shall see further on what has to be done; but the others are annexes for treating those who are almost convalescent. This treatment should be both medical and psychical; and as it is advisable to give the patients a feeling as of a different life, the fact that the annexes are not near the administrative centre, though inconvenient in some respects, has advantages which would not exist if the patients had simply been removed to another part of the same building.

Medically, there should be a general tonic treatment: hot and cold hydrotherapy, a suitable dietetic regimen; administration of arsenic, phosphorus, and strychnine; rest and relative quiet.

Psychically, according to the case, there should be a gradual resumption of activity. Especially, and as soon as possible, we should try to avoid idleness. There are some difficulties with regard to this, and we must be on the alert to seize the moment at which the

patient is capable, and feels the need, of learning to work again. Whatever the nature of the mental disorder may be, except when it was a quite transitory episode, whenever there has been a true disease of the brain, the resumption of cerebral activity is slow and painful.

Reading should not be overdone. Even to those who could not do without it in ordinary life it is tiring, quite as much through the visual effort of fixation as from the exertion of general attention. Neither should the patients be allowed to play overlong at any *games* requiring much physical exertion, or considerable intellectual effort. We should start from the principle that the more perfected a brain has been, either by its development in the course of preceding generations, or by individual acquisitions, the more unstable it is. Those of the shell-shocked who belong to the intellectual professional classes are among the most severely affected. It is not uncommon to come across an officer who has been trephined or shell-shocked, whose moral is excellent, and who is most anxious to go back again, who will say to you : " In the field I can pull through all right, but they must on no account give me a post in an office, for as soon as I begin to read or write, my head goes all to pieces."

There are patients who may be successfully utilized for the domestic duties of the institution in which they are placed. Care should be taken not to overwork them, and not to allow those patients whose circulation is slow, and who easily get cerebral congestion, to do too much stooping work. Sometimes it would be better for them to make various little articles, such as are made by the wounded men.

When possible, the best work for them is *agricultural labour*. But even with that, great caution is required. It is contra-indicated in trephined cases when the scar is painful, especially if there is also a tendency to sudden rushes of blood to the head. For the same reason it cannot be indiscriminately advised for all

the shell-shocked, though it would be beneficial for many of them. Professor Bergonié has recently reminded us of the physiological advantages to be gained from working on the land, and we should remember his valuable suggestions.

By its very nature, through the amplitude and rhythm of its movements, it has a potent influence on the circulatory activity; and if the patient can stand it without getting out of breath, and so far as that is concerned the exertion may be graduated, if they are able to stoop forward for any length of time, and if they are not unduly susceptible to the sun's rays, the work will have a very good effect on them. However, precautions should be taken against sunstroke in any case. As it is by no means our purpose to form a squad of farm labourers, equal to those of healthy men on leave, they should be allowed to work only in the early morning and late afternoon, when there will be no risk of sunstroke.

Agricultural labour answers very well for the shell-shocked who are subject to fits, though less decidedly so than for those in whom the element of mental confusion predominates. Still, in cases of patients who have fits of but slight or moderate intensity, it may be tried, though very cautiously, because of the danger incurred by the use of agricultural implements.

The workers should be supervised by absolutely trustworthy attendants, who will not allow them to look on their work as an excuse for drinking. No impulsive, unbalanced patients, no true epileptics, and no shell-shocked cases subject to violent fits, should be allowed to take up agricultural work.

II.—RETURNS TO THE CORPS

For an ordinary wound, not seriously affecting the general condition, convalescent leave is not necessary, and the regulation leave of absence may suffice. But on the other hand, for those patients whose minds have been affected, a return to the front direct, or

after the week's leave, is the exception. Whenever there has been serious mental disorder, it must be recognized that it will be a prolonged affair, or rather that the patient will remain weak for a long time.

§ 1. Returning Straight to the Front

Some men should be sent straight back to the front; and when they cannot be at once sent on to their regular station, it may be necessary to give notice to the chief medical officer of their dépôt, asking him, and giving reasons in support of the request, to include them in the next reinforcement. The patients who should be so returned are the utilizable unbalanced ones, the conscious and amendable undisciplined ones, and, most especially, the habitual drunkards. No man who we know beforehand is sure to run away, or get himself called up before a court-martial after a fit of drunkenness, but who is fit for the fighting-line and shows no sigh of permanent mental disorder, *should be allowed to remain in the dépôt.* Such men should even be invariably deprived of the regulation week's leave of absence when they come from the front. The dépôts, with their lack of occupation, their hours of liberty, the near neighbourhood of public-houses and other attractions of town life, only serve to aggravate cases of this kind, and make them worse.

§ 2. Returning to the Dépôt or the Factory

A return direct to the workshop or the dépôt without convalescent leave is indicated for all slightly affected cases, and for the fairly numerous cases that did not allow of convalescent leave, *e. g.* those for whom it was better to remain under hospital régime until they were completely recovered. Because of the difficulties which psychiatry offers to those doctors who are not familiar with it, we should not merely content ourselves with seeing that all the papers concerning the case are in order, but we should also write a sealed note to the chief medical officer, which will acquaint him with the

patient's special symptoms, and, in case of need, serve as a guide to the way in which he should be treated.

Many patients who had been wounded, and in whom mental confusion followed on fatigue and illness, and who are worthy of real interest, are received on their return to the dépôt with raillery, or with a suspicion which is quite as bad for their mental condition. All the same, we should be very careful to give due warning when we send back an exaggerator. At the beginning of the campaign, before special centres had been established, the exaggerators and the persistents had a fine time of it. By getting themselves sent from one hospital to another in different formations, and from whence they were sent back to the dépôt, they prolonged the situation. The collection of all the documents in the case, and their transmission to consultative centres, have put an end to these practices.

§ 3. Internment

It is evident that as the material and administrative organization of the centres proceeds, it will not always be necessary to intern the same class of patients. If the centre can dispose of a certain number of beds in a neighbouring lunatic asylum, acting as an auxiliary hospital, and completely militarized, we may be able to avoid a formal internment of many of the patients. If, on the contrary, the lunatic asylum is only run on the same lines as in peace-time, we shall be obliged to intern a considerable number, temporarily at least.

Indeed, among those patients whom we receive in the central service, two types demand, if not legal internment, at any rate a sojourn in a lunatic asylum. On the one hand, there are the chronic, not to say the incurable, cases, such as those of dementia and chronic persecutory madness with dangerous tendencies, etc.; and on the other hand, there is the essentially transitory condition of extreme excitement, with dangerous tendencies. For these last patients a special installation and an experienced staff are necessary,

otherwise we find ourselves forced to employ the prolonged and objectionable methods of control of another age; the other patients are injured by the proximity of the excited one: and, finally, there is always a risk of accidents occurring. Those also who have distinct suicidal proclivities should be interned. As regards these last, we should remember that up to the time of their transfer to the asylum they should never be left alone in a room, not even when the window is shut and the furniture restricted. No orders given to an attendant will protect a patient left alone in a room from suicide. It would be much better to leave him with forewarned and attentive comrades.

The period of internment may be very short, for alcoholics, for example, or for maniacs who, once the great excitement is over, may be returned to an ordinary hospital of the centre. Also, it is advantageous for the head of the centre, if he has no direct authority over the asylum, to keep in communication with its chief doctor, so as to be able to withdraw the patients as soon as possible.

After a preliminary agreement between the prefectorial administration and the military authorities, internment takes place under the legal form of a voluntary entry, charged to the account of the Ministry of War, into the departmental asylum. In such a case two documents suffice to effect the entry without delay. These are a medical certificate and a request for admission on account of the war, signed by the chief doctor of the hospital in which the patient to be interned is staying.

With regard to those asylums for which no agreement has been made between the prefecture and the medical department, the latter is obliged to ask the prefect to make out an official order for internment, which entails delay, and sometimes difficulty, as the prefectorial department may hold a different opinion from that of the medical department, as to the dangerous character of the patient's disorder and the need for an official and prompt internment.

As we have seen, it may be sometimes necessary to intern *curable* lunatics. It is, therefore, advisable to counteract that confusion between men who should be interned and men who should be discharged that only too often exists in the minds of the public, of departmental officials, and even among doctors. They are not at all the same thing, and if instructions given before the war considered discharge to be necessary for all interned men, it was solely because of that perpetual mistake between acute mental disorders and chronic insanity.

§ 4. Convalescent Leave

Convalescent leave is both a method of treatment and a means of awaiting the right moment for the clearing up of certain cases that could not legitimately be settled without delay.

Patients on convalescent leave may be sent to their families if these latter express a wish for it, and are able to care for them properly. When this is not the case, they can be sent to one of the convalescent homes for invalid soldiers. Before suggesting a convalescent leave to the competent committee, it will be necessary to find out if the man has a right to any present and advance pay. The origin of the illness, a question which is of capital importance with respect to discharge, and of which we should always try to ascertain the answer as exactly as possible, so that all the papers in the case may be correct, intervenes as regards convalescent leave also.

To whom should we grant leave? To the greater number of those affected with acute mental disorder, and who need to regain their strength little by little. We should try to find out beforehand what the patient's family is like, how they live, and what their habits are. We should talk with the relatives who come to see him, and put them on their guard against alcohol as a "restorative," and also against overfeeding him, to which last proceeding families are

only too much inclined. If possible, we should tell them what occupation the patient may indulge in.

Likewise we should do well to grant convalescent leave to all those patients whose condition appears to be chronic, but likely to improve substantially, either through a natural process, or because the diagnosis was open to doubt. It may be thus with slightly affected persecutory cases, or those in the early stage of primary dementia.

Moreover, we should grant convalescent leave to men who are temporarily or definitely invalided through the war. Such a leave has two advantages. It will allow time for the amelioration of the morbid symptoms : there is sometimes a very distinct improvement in the course of a few months. In this way the patient is less incapable when the time for his final discharge comes, and the rights of the State are protected. Also, this delay allows of making all necessary inquiries, and collecting all the papers concerning the case. When we send in to the committee the proposal for a convalescent leave for such patients, we should recommend that at the end of their leave they should return to the centre at which they were when it was granted to them. Regulations used not always to permit of these convalescent leaves, followed by a return to hospital, but in mental cases they are invaluable. Better than any other arrangement, they allow of our leaving at liberty those patients as to whose mental state there may be grave doubts, but who, on the other hand, are not so disordered as to make it necessary to keep them, possibly for quite a long time, shut up in a lunatic asylum, or even in a hospital.

Merely to return to the command dépôt does not, as a matter of fact, offer any safeguard to either the most interesting or the most dangerous of the mentally disordered.

For the first—those who were wounded or shell-shocked—the absence of wounds, or their having healed, makes it difficult for the doctor at the dépôt to distinguish them from exaggerators. As for the

dangerous patients, especially the persecutory maniacs, who hide their delusions with the greatest care, they may, if they go straight back to the dépôt, be included in reinforcements sent to the front, where there would be a risk of their bringing about some mishap. So, whenever the medical chief of a centre does not feel certain that he can free himself from all responsibility concerning a patient, he should see to it that the man has the chance of returning to the hospital.

What should be the length of the leave? Very long. At the beginning of the campaign I thought myself generous when I proposed a convalescent leave of forty-five days for a shell-shocked confused patient. Now, like Professor Grasset, who has several times laid stress on this point, I have recanted this optimism, and so far from regretting having given unduly long leaves, every week I am surprised by receiving a request for information or for the papers concerning former patients sent away as convalescent, and who, though apparently quite recovered, have drifted from a hospital to a final discharge after their return to the command dépôt. Indeed, for a seriously shell-shocked case, with loss of consciousness at first, and a stay in hospital of from one to two months (including both at the front and in the rear) a convalescent leave of two months is normal. Often it will not suffice. Sometimes, especially if there are still lapses of memory and a tendency to fits of congestion, we may ask for three months' leave straight off.

Likewise in slight or medium cases of attacks of confusion, two months is the minimum. Only for the very lightest cases will one month be enough. As for serious mental confusion, trephining with a cerebral wound, or even a simple opening of the dura mater, or shell-shocked cases with a persistent syndrome—for example, with signs of general paralysis—for all these cases three months' leave is required. As also for cases of chronic delusion, general paralysis, and primary dementia, and for grave cases of melancholia, and the consequences of a definite attack of

mania. On the other hand, mild cases of melancholia do very well with from one to two months' leave. *Patients with suicidal tendency should never be sent on convalescent leave.*

We should give the shortest possible leave to alcoholics and to those who take drugs, for there are cases, though they are very rare, of morphino-maniacs and cocaine-takers who have slight attacks of mental confusion.

§ 5. Auxiliary Service

Change of Arm. Special Cases

Many of our patients can certainly not go back to the fighting forces, or to their original arm. There are, therefore, proposals to be made as to their position and as to their employment, leaving out those to be discharged, whom we shall find again further on.

Classification in the auxiliary service is fairly often applicable, either on the score of some military reason, or as resulting from a condition independent of the war. It answers for moderately shell-shocked cases who are practically capable of regular work, but who are still weak, and especially susceptible to noises and shocks. They should on no account return to the front, neither should those who had slight wounds in the head, and who have been trephined, even though the dura mater was not opened or the internal table involved; nor, again, those with a healthy well-ossified, cicatrix with a minimum of congestive symptoms. *In any case, except for those who received very slight injuries, all patients with head wounds are definitively unfit to serve at the front.*

It is the same with regard to the utilizable depressed melancholics, certain confusional and mild delusional cases who seem to be cured, as also with those who have very rare attacks of mania, and with a considerable number able to serve as labourers, but whose place is most certainly not in the front line. Unfortunately,

it only too often happens that there are no special cadres for these feeble-minded persons, so that in the long run they cannot even serve as labourers, because their non-commissioned officers or their work are changed too often. They then become useless, distracted, go all to pieces, and nothing more can be got out of them. And yet, behind the almost animal look of their faces, an intelligent expression will suddenly illuminate their countenances when they have to do something they can understand, or anything that is on the level of their capacities, or to which they are accustomed. A feeble-minded patient who, while in the hospital, was entirely inert, confused, and timid, and who seemed to be quite incapable of looking after himself, received his discharge; and at the time of his departure, as we were making arrangements in his presence for some one to accompany him, he joined in the conversation, saying " Oh ! I shall quite well be able to recognize my own village ! " He was not a simulator, neither was he playing the fool. He only had a limited number of acquisitions at his disposal, and could not get on away from the rule of thumb by which he had always lived.

We should not put any patients into the auxiliary services whose condition is bound to grow worse, such as *general paralytics* in the early stage, not even when disease is advancing very slowly. It is the same with sufferers from *premature dementia*. We should also exclude all those who may become dangerous at any given moment. An exception may be made of those *epileptics who have fits only very rarely*. These may very well be dangerous at the time of their fits, on account of a psychic equivalent, as we have already seen. But when the fits do not recur except once in every five or six months, and *are not habitually accompanied by psychical manifestations*, we make it the rule not to discharge them, but to offer them to the auxiliary service, with a warning to the regimental doctor. This precaution is indispensable. These men cannot be kept in the army except on condition that they never

have any especially dangerous duties to perform—their existence should not be any more endangered by a fit than it would be in civil life. Otherwise, the responsibility of the State would be too heavy. So do not let them ride on horseback or on a motor cycle, or do motor driving.

At the Paris Centre, Marcel Briand has made an analogous arrangement which he made known through a communication to the Société de Médecine Légale (5 juillet, 1915). It is to be noted that the invaliding committees generally consider themselves to be bound by Article 53 of the instructions concerning physical aptitude for military service, which is as follows: "Epilepsy" (mal comitial) "is a reason for exemption and discharge," and make difficulties about admitting proved cases of it into the auxiliary services. If we cannot come to an understanding with the committee with regard to those cases who have fits very rarely, we may adopt the following formula, suggested by Marcel Briant: "Nervous disorders—manifesting themselves intermittently, and which are of a type incompatible with active service at the front, but which are, owing to their rarity, quite compatible with service in the auxiliary forces."

It is best to take a fairly lenient view with respect to passing into the auxiliary service those patients who have slight remains of encephalitis, or who have recovered from otitic cerebral complications, as also for a certain number of neurasthenics and neuropathic cases with no power of physical resistance, and who could not stand the full training. But with regard to those whose circulatory system is adequate, whose sleep is not seriously disturbed, and in whom there are no tubercular tendencies, we may, on the contrary, send them back to their regiments with a warning that they will require care to begin with, and should be subjected to a graduated training.

Thus, to place them in the auxiliary service is a useful measure for many cases. It would be a perfect one if the recruiting agencies were better informed

as to the physical and mental capabilities of each case, so that every man could be certain of being put to work he could effectively perform. Unfortunately, the recruiting agencies have no information as to this, the invaliding committees give them none, so that we may see a shell-shocked man, in whom the least sudden noise causes vertigo and shooting pains in the head, employed in a boiler-making factory, or some other metallurgic workshop.

We are sometimes consulted about a request to be permitted to make a *change of arm*. We cannot pass in review all the cases that may present themselves. Besides, special aptitudes are required for the different arms, especially for aviators (the pilots), for whom a strict examination as to their nervous and mental condition is advisable.

Special Cases. Unstable and Unruly Unbalanced Cases.—Finally, there are special cases concerning which there is always considerable difficulty. I have referred to that of the epileptics who only have occasional fits. That of the unstable and unruly unbalanced patients is much more instructive.

They have evidently diseased, or, at the very least, badly developed brains. This has been pointed out before, and agreement on the subject is unanimous. In the long run, after a more or less prolonged adventurous life, they end in the lunatic asylum; and Haury in particular has done useful work in recording the presence of former French deserters at the Bel-Air Asylum at Geneva. But those doctors who are competent to decide the matter agree as to another point, and that is that many of these scamps would be quite useful if they were properly managed, and only put to work for which they are fitted. The African troops have always included a notable proportion of such men, especially among the volunteers. And in the course of either colonial expeditions, or that of the present war, the reputation of these troops stands high. It is likewise a proof of their possible usefulness that many of them who had been discharged because of mental

disorder volunteer again, and sometimes succeed in settling down, for a time at any rate. Only, the army is not prepared to receive them, it has no special military formations suited to them, and more especially it has not a sufficient choice of cadres which unite a very strict discipline with a rigorous sense of justice, and, at need, a certain degree of indulgence.

That they are very difficult to command is well understood, so much so that they cannot be led solely by force. They are not afraid of their officers; an act of indiscipline more or less is nothing to them; and if with the idea of curbing them they are provoked beyond endurance, the consequences on a day of battle may be very serious. Then their personality is an encumbrance and their example dangerous. Medical Inspecspector Simonin, who made a comprehensive study of them in an article dated 1909, pointed out the practical difficulties of utilizing them.

So we should not be too surprised that it has not been possible to fulfil a desire expressed by the Medico-Psychological Society in July 1916, after hearing a communication from Nordman and Bonhomme, and a discussion in which Colin, Pactet, Dupré, Lwoff, Trénel, Jean Philippe, and Haury took part, and which was followed by a report from the last named. It was pointed out that though the utilization of these abnormal men is difficult in peace-time, yet in war-time it is desirable, and would be quite possible if special companies were formed at the front, preferably in Morocco or the East, of men who had previously been mentally examined in a specialized centre by an alienist physician. These men should never be allowed to remain at the command dépôts, for the same reasons as I gave with regard to alcoholics.

The War Office, which also we had asked to create special formations for cases of neurological persistency, did not think that the considerable difficulties which the creation of these special corps would give rise to would be sufficiently compensated for by

the number of effectives it would provide, and though it regretted having to exempt from the blood-tax those who seemed in every respect fitted to pay it, the War Office ordered the discharge of all those who could not be utilized in normal units.

§ 6. Discharge No. 2

At the beginning of the war, a number of men received their Discharge No. 2 simply because they were insane, or were looked on as such. Owing to that mistaken idea, which I have before spoken of, it was believed either that they were definitely insane, or constitutionally and inevitably bound to become so. Now, among these patients many have recovered, and others were direct victims of war. In either case Discharge No. 2 was unjustifiable. As we have seen, predisposition does exist in many cases, but not to an equal degree. Therefore, Discharges No. 2 are less frequent at the present time. When the mistakes which were made to begin with were recognized, official instructions were issued, specifying the duty of doctors and committees, who, before deciding on Discharge No. 2 were ordered to make sure that no military occurrence had brought about the need for it. This, as we shall see later on, led to a great increase of Discharges No. 1.

Nevertheless, Discharge No. 2 is still the necessary measure for a large number of patients, such as we see more especially in the rear centres; for in the army centres we are more likely to find patients with whom an episode of war has been a determining factor. But the centres of the interior have to deal not only with those patients who could never be sent to the front at all, and who, either as auxiliaries or unfit, encumber the command dépôts for a longer or shorter time; but also with those patients, previously exempted or discharged, who have recovered; and also with those cases that had received No. 2, or temporary discharge,

and that, under the Dalbiez Law, were subjected to a re-survey and taken back at that time. For it must be admitted that these mental disorders are a kind of Sisyphean stone, always rolling back into the specialized centres. We have discharged patients who have been brought back again after a re-survey at three months, and we have discharged them again, after which they have re-enlisted, and come back to us again for a third discharge.

The categories amenable to Discharge No. 2, and the enumeration of which should replace the short formula " mental alienation " of former instructions, are the following, among others :—

Those psychoses that are chronic from the first onset, that is to say, *imbecility*, *idiocy*, *mental debility* (when it amounts to a certain degree), *chronic persecutory delusions*, the *mentally unbalanced* (as described in a preceding paragraph); also *maniacal depressive psychoses*, that is, *melancholia*, *chronic mental confusion* (not caused by an episode of war), the *important sequelæ of wounds in the head not received when on active service*, and, under the same conditions, the *deep-seated remains of encephalitis*, *established epilepsy* (except for those cases which can be placed in the auxiliary services), also *proved somnambulism*, certain *seriously hysterical patients*, *sufferers from depressive states*, and former *neurasthenics* (not having become so through the war, and whose physical condition is but mediocre), *established psychasthenia* (seriously obsessed, important phobias, except those who may be utilized in the auxiliary service), *organic dementia*, *cerebral arterio-sclerosis*, *tabes with mental disorder*, and *general paralysis*, except for those cases to be referred to later on.

As regards a certain number of these patients, more especially for all youthful neuropaths and cases of depression, which are likely to improve as time goes on, we should substitute for Discharge No. 2, the first class temporary discharge, which means without a gratuity.

§ 7. Discharge No. 1 and Temporary Discharge without a Gratuity

Facts having transformed all prevailing ideas on the subject of the discharge of mental patients, the War Office found itself faced with very different problems in those cases in which an episode of war was a recognized factor. The diversity of experience concerning them led to divergencies among the experts which it was necessary to put a stop to. This was the work of a conference between the Neurological and Psychiatrical Societies and the heads of the Army Neurological and Psychiatrical Administrative Centres, which took place on December 15, 1916, and at which two reports were discussed, Dupré's and mine. The conference agreed that in an important number of cases circumstances of war should be considered a factor, and Discharge No. 1 decided on; or generally and more exactly, a temporary second class invaliding, *i.e.* with a gratuity. I especially insisted on the gradual but possible improvement which justifies a subsequent revision of the pension for incapacity.

With regard to those *acute conditions* which are yet sufficiently lasting to make it henceforth impossible for the patient to serve in the army, and which are due to a cranio-cerebral wound, or to shell-shock, even when entirely emotional, or to toxi-infections, that discharge should be decided on with a pension for incapacity equal to the proved degree of the latter, that is to say without taking predisposition into account, and graded from 10 to 100 per cent. I recall, from memory only, that there is good reason to class slight cases of trephining very freely with those who should be temporarily invalided, rather than in the auxiliary services.

With regard to *demential states*, or *definitive psychical impairment* due either to traumatism or infection, it is useless to speak of temporary invaliding. We

should award Discharge No. 1, with a pension of 50 to 100 per cent.

Likewise, for *chronic post-confusional psychoses*, Discharge No. 1, with incapacity 20 to 80 per cent.

In maniacal and melancholic conditions, if the origin of the first attack may have been through a wound or serious infection, temporary invaliding with pension 10 to 40 per cent.

Two cases gave rise to a lengthy discussion : *general paralysis* and *epilepsy*. With regard to general paralysis, the solution adopted was the following : Discharge No. 2, save for those exceptional cases in which an encephalic wound may be legitimately considered to have accelerated or aggravated the disease, in which case a pension of incapacity of 10 to 30 per cent. should be granted. Some members of the conference were strongly opposed to any gratuity, however small, being granted to any general paralytics whatever. Their argument was that general paralysis is a parasyphilitic disease in any case, directly dependent on syphilis. Under such circumstances it makes very little difference whether circumstances of war did or did not hasten the development of the disease. Indeed in their view, war could have nothing to do with it. I held the opposite opinion, and endeavoured, apart from all doctrine, to gain a victory for the sensible and just idea that *sometimes*, exceptionally, the circumstances of war may not have been absolutely irresponsible for the development of the disease.

There are cases of it with wounds in the head, but there are also cases without them. As a matter of fact, the most generally held opinion is that if syphilis is the indispensable origin of general paralysis, it is in itself a quite sufficient factor, and that no other determinating cause should be invoked. This formula seems to me to be medically inexact, and practically unjust. General paralysis is not solely syphilitic. It is syphilis *plus* something else unknown to us, but which, doubtless, is either a particular virus, or simply a constitutionally prepared soil. Wounds, as Régis

among others has clearly pointed out, physical, intellectual and moral over-fatigue, and insomnia, are factors the clinical importance of which we cannot fail to recognize.

These observations were borne in mind, and assisted towards the adoption of an exceptional pension for incapacity of from 10 to 30 per cent., but only for cases with injuries to the head; this term, however, being taken in the widest sense. Nevertheless, this decision was far from being that which I proposed in my report, raising the eventual pension to 40 per cent., and especially admitting determining causes, such as over-fatigue, under the conditions I have just spoken of.

The Clinical Society of Mental Medicine, and the Psychiatrical Society of Paris, in a conference to which the heads of administrative centres also were invited, returned to the study of this question in consequence of a report of Pactet's, renewing my own observations based on them, as also on the results of the experience gained by him in his work at the front and in the rear. His authority and that of St. Colin led to the adoption of the following formula, which has now become the rule: "For general paralysis Discharge No. 2, except for those particular cases in which a minute inquiry has proved in peace-time, and more especially in war-time, the aggravating influence of military service: in such cases incapacity of 60 to 80 per cent."

This very liberal formula is entirely justified in my opinion if taken literally, that is to say, if a minute and close inquiry brings proofs, or at the least very strong presumptions. For example: an artillery officer who, during the whole of the spring of 1916, remained without being relieved and without a single day's rest in a very lively sector of the Verdun region. We may imagine what his days and nights were, during which he had moreover to endeavour to carry out his calculations. Up till then he had got through his eighteen months at the front without any difficulty. After that prodigious episode of exasperated nervous tension, he

became—without an actual shell-shock or wound—a general paralytic. Can we possibly say that the war had nothing to do with the production of his symptoms?

Of course, since we accord to the partisans of the entirely syphilitic origin of general paralysis that there always is a syphilitic element in it, the verifying thereof by the Wasserman test has no importance whatever as regards invaliding.

Concerning *epilepsy* also a discussion took place between the partisans of inevitable epileptic neurosis, and those of an epileptic syndrome of variable origin, and not immutable. A. Léri furnished a valuable argument to the cause of acquired epilepsy, by reporting cases of Brown-Séquard's epilepsy caused by peripheral lesions, similar to those reported by Mairet and myself. The formula adopted after the discussion was as follows: "That form of epilepsy termed essential always gives ground for Discharge No. 2, save for those exceptional cases in which an injury or a serious infection can be invoked as a causative episode of war, preceding the appearance of the first epileptic symptom. In these exceptional cases, Discharge No. 1, with pension for incapacity of from 10 to 80 per cent."

§ 8. What Remains to be Done

As we have seen, the therapeutics of mental disorders in the army is nearly organized; the appropriate military measures have already become clear, and grow more distinct every day. What still remains to be done to hasten their progress?

In the first place, the old official doctrines relating to mental disorders should be brought up to date. It should be clearly understood that we may be obliged to intern a patient suffering from acute mania, without it being necessary to discharge him from the army later on in consequence.

Next, extend the facilities for expansion and work already accorded to the psychiatrical centres. Well

supplied with the necessary appliances, and provided with an ample *personnel*, they are excellent instruments of treatment and prophylaxis. Utilize all the specialists to this end, and reappoint all those who are wrongly employed in unsuitable posts.

Develop the out-patients' consulting-rooms annexed to the centres. Recommend their use at the command dépôts for doubtful cases, examination before admission, etc.

Create as soon as possible *asylums for the non-dangerous incurable neuro-psychiatrical cases*. It is sad to see those who are among the most cruelly stricken victims of the war, men who have undergone trephining and who are seriously disordered in mind, shell-shocked cases, and organic paraplegics, reduced to the lunatic asylum or to utter poverty; for such as they stand in need of care, which, when once they re-enter civilian life, they are unable with their small pensions to obtain. On the other hand, they cannot continue to encumber the institutions, which are hospitals, not asylums.

Utilize the Auxiliaries in a Rational Way.—Do not put those who cannot bear to hear the stroke of a hammer to work at metallurgy. Organize, with the special co-operation of the neuro-psychiatrical centres, agricultural groups for the shell-shocked, and certain cases of depression, which should be withdrawn from barrack life, and are unfit to take the field.

Complete the Dalbiez Law by provisions *forbidding the recall of dangerous lunatics* at the end of three months; and at the time of re-examination compel the discharge committees to inquire into the cause of the preceding invaliding, and *if it was due to a mental affection to forbid recall* without the assent of the psychiatrical centre. Urgently impress on the discharge committees that they should not, as they too often do, recall trephined patients, temporarily invalided after due inquiry and medical examination, without another careful examination and expert opinion. Several times we have seen trephined patients who had been temporarily invalided, then called up

again, subjected to a harmful degree of exertion, and made worse in consequence.

Make the discharge committees understand that it is to the general advantage that they should in mental cases conform their opinions to those of the heads of the centres.

(After some difficulty I managed to gain in this respect results which should be generalized.)

In deciding on Discharge No. 1, complete the very benevolent provisions which have been sanctioned, by a study of the *former state of the patient.* This innovation with regard to pensions and gratuities is necessary if we do not wish to see the cost of pensions rise far too high. We are no longer under the régime of peace-time; the State no longer claims only young and healthy conscripts; it incorporates reservists of the older classes, some of whom have acquired defects for which it would be scarcely legitimate to make the State responsible because of some slight war casualty. Alcoholism is the originating cause of a good number of these acquired defects, and by itself alone would justify our taking into consideration the patient's former condition.

§ 9. Conclusion

France, whom the people across the Rhine declared to be degenerate, who seemed to have forgotten her martial virtues, who had, alas! ceased to be sober; France, seized, as it were, while still dreaming, by the cataclysm of war, has mastered her nerves and braced her energies. Her troops, insufficiently prepared, subjected to a strain which surpasses human imagination, have adapted themselves, not to the selfish struggle for existence, but to the fight for their country and their race; to a daily and willingly renewed sacrifice in the midst of death. Taken altogether, their health has not given way, and their nervous system only bears the natural stamp of battle. Neither in the hell at Verdun nor elsewhere have there been any mental

epidemics, either through fear or through horror. Among us, nothing has recalled that great wave of general insanity that occurred in the Middle Ages; and if there are pychoses of war, it is because these psychoses are not solely diseases of the mind.

The spirit of the army, which has been marvellous, would have been better still if it had not been for the existence of great social defects. Moreover, it is not we alone who have paid tribute to them. Ladame has disclosed that in the Swiss Army during the first year of mobilization, alcohol and syphilis together were responsible for sixteen per cent. of discharges, and tuberculosis for sixteen more. Consequently, we know what remains for us to do; for, if the treatment of mental disorder is sometimes successful in cases of declared disorder, it is always so in prevention. The army psychiatrical centres have devised treatment of mental disorders in their earliest stages, the success of which is a guide to psychiatry in general for the future.

SECTION IV

WOUNDS OF THE PLEURA AND OF THE LUNG

WOUNDS OF THE PLEURA AND OF THE LUNG

ETIOLOGY

Frequency.—Pre-war statistics show that wounds of the chest represent a mean average of 10 per cent. of total wounds. In an evacution hospital attached to the Motor Surgical Unit of G. Gross, 39,309 wounded passed through during a period of seven months in 1916. This period synchronised with great military activity at the front. Out of this number, it was stated on the Field Medical Cards of 2,210 cases that they had wounds or injuries of the chest which represented 5·6 per cent. of the total number of wounded.

Latarget notes that during the offensive in Champagne in 1915, 9,328 cases were admitted to his hospital in four days, of whom 328, or 3·5 per cent., had penetrating wounds of the chest.

Schmid, in an advanced formation at the beginning of the war, saw 64 chest wounds, or 7 per cent. in a total of 900 wounded.

Duval, during the Somme offensive, had 163 wounds of the thorax out of 2,200 cases at his Motor Surgical Unit, which is roughly equivalent to 7·8 per cent.

There should, however, be no delusion as to these figures representing the total number of chest wounds. They only indicate the percentages of such wounds which reach hospitals at a considerable distance from the fighting line.

If we obtain data for such statistics at an aid post, those killed in the field will not be taken into account. A fairly large number of wounded, who, in the overcrowding inseparable from an attack, cannot be kept under observation long enough to ensure a precise diagnosis, will also be omitted. In some cases a chest wound, owing to the presence of other injuries, escapes notice, at least at first. Conversely other cases labelled "wound of thorax" are found later to be quite superficial injuries.

Are statistics to be collected on the field itself? Even if possible, it would be found to be impracticable. Some wounds may be concealed by the clothing on the corpse; some are so extensive that they baffle description. On the field of battle at Champguyon we saw a soldier lying face downwards on the ground; the growing grass was visible through his pack. In another place, an officer had been cut in two by the explosion of a shell. Could these be described as wounds of the thorax?

These figures, therefore, are of little interest.

The Traumatic Agent.—The weapons which cause the wounds are extremely varied. In fact, everything used in warfare, and the greatest variety of projectiles, have been known to inflict chest wounds: bullets, shells, bayonets, sabres, lances, etc. We once found the key-opener of a sardine-box in a sergeant's chest; and in the chest of another man a piece of tibia, which must have belonged to a comrade, as the man himself had no other wound. Although it seemed early in the war that bullet wounds were in the majority, conditions are changing, and we now find that shell fragments are almost exclusively the cause of pleuro-pulmonary wounds, and that bullet wounds have become the exception.

These differences may be estimated by comparing the various statistics furnished since the outbreak of war.

G. Gross, from 171 chest wounds seen from the commencement of the war to the middle of 1915, reports:

123 cases by bullet, or 72·4 per cent.

48 cases by shell fragments, or 28 per cent.

Schmid, under the same conditions, of 64 cases, found:

44 by bullet.

20 by shell fragments.

Depage and Janssen, out of 360 cases at the Ambulance de la Panne, from Dec. 1914 to the end of 1916, give the following figures:

182 injuries by bullet, or 50 per cent.

146 by shell, say 41 per cent.

26 by shrapnel, say 7 per cent.

5 by cold steel.

2, cause unknown.

Maillet, out of 122 cases examined from the beginning of the war to the end of 1915, found:

51 injuries by bullet.

70 by shell fragment.

1 by bayonet.

Duponchel, from April 8th to June 18th, 1916, saw 269 wounds of the thorax; all were by shell fragments.

During a period of seven months in 1916, one of the authors examined 362 chest injuries:

302 had been wounded by shell fragments.

25 by bullet.

30 by grenades.

4 by bombs.

1 by bayonet.

It is evident, therefore, as the war advances, that the preponderance of wounds by shell fragments is becoming more and more marked; grenade and bomb wounds are only found occasionally, usually at times of infantry attacks, raids, or other offensives, and bullet wounds are only seen when men are exposed to machine-gun fire.

PART I

WOUNDS OF THE PLEURA AND LUNG WITHOUT INFECTION

CHAPTER I

PATHOLOGICAL ANATOMY

GENERAL CHARACTERS

THE weapon or projectile which causes the wound is the important factor in deciding the general features of pleuro-pulmonary wounds; it must constantly be taken into consideration.

Number.—In the great majority of cases, the wound is *single*: this is the characteristic feature of bayonet or bullet wounds, but is frequent also in those due to shell fragments. The right and left sides are wounded in the same proportions; our statistics give us equal figures in this respect.

Multiple wounds are met with, especially from shell fragments. Special mention should be made of the wounds produced by the bursting of grenades, when the chest may be covered with an infinity of wounds, several of which are penetrating.

Bilateral pleuro-pulmonary wounds are not exceptional. But in these cases we must distinguish between those in which both sides of the chest have been injured by several projectiles, and those in which the chest has been traversed from side to side, by a single projectile.

Course.—Wounds may be *transfixing*, the projectile passing right through and emerging at the opposite point of the thorax.

Wounds may be *blind*, without aperture of exit, the projectile or projectiles remaining in the cavity of the thorax or in any other part of the body which they may have reached.

Wounds may be of "*seton*" *form, with apertures adjoining* (G. Gross), the *perforation en écharpe* of Delorme. The projectile strikes the thorax obliquely, and the wounds of entry and exit are often close together: in its intra-thoracic course, it may simply wound the pleura, or may injure the lung at the same time.

The degrees of penetration and the paths followed by the projectiles are essentially variable and depend upon factors which are different in each case: distance, the attitude of the man, the nature of the projectile, etc.

Bullet wounds are usually transfixing. The course taken by the projectile may be antero-posterior, transverse, or oblique; when the man has been hit, while hiding behind some shelter, lying down, or running with the body bent forwards, the bullet, entering the upper part of the chest, may come out behind at a lower level. In other cases the projectile penetrates the chest, after traversing the shoulder or the arm, or having crossed the lateral or anterior surface of the body at an angle.

When the bullet remains in the body, it may stop in the lung, pass through it, and come to rest under the skin of the opposite side, or sometimes pass still farther for some distance. These facts explain the association of wounds of the spinal cord, abdominal and renal injuries, etc. Endless examples of this might be quoted.

The character of wounds by shell fragment, the explosion of shells, and of grenades, depends mainly upon the size of the projectile.

Small fragments cause through-and-through wounds,

or seton wounds: they are usually multiple and therefore the possibility of the same patient on whom seton or transfixing wounds are found also having fragments retained either in the pleura or in the lung must not be overlooked.

Large fragments usually cause death within a comparatively short time, as they produce extensive and irreparable damage. A man struck in the subclavicular depression by a piece of shell about the size of an egg, which caused death in a few hours, had a fracture of the clavicle, a vertical seton wound of the lung, and an enormous tear in the diaphragm through which the whole stomach had passed into the thorax ; further, the spleen was ruptured, and the missile was lodged in the descending colon.

EXAMINATION OF THE LESIONS

MACROSCOPIC LESIONS

We propose to discuss the lesions of the skin and subjacent tissues, of the bony skeleton, and of the pleura and lung.

1. Skin and Subcutaneous Tissues

A bullet impinging directly at a range of about 200 to 1,500 metres usually passes through the chest, and produces punctiform wounds of entry and exit. The edges of the wound, soiled only with a little coagulated blood, are accurately approximated.

But this does not always happen, and at other times the margins are torn, everted, and retracted, exposing the deeper layers. The adjoining tissues in these cases are almost always more or less swollen, and a fairly extensive *hæmatoma* may radiate from the margins of the wound.

In a certain number of cases the lacerated margins may be raised by a zone of either localised or more

extensive *subcutaneous emphysema*, a complication which we shall have to deal with later (see p. 768).

Finally, cases occur in which the skin wound shows considerable loss of substance, which may appear to be limited to the superficial layers, whereas its edges often bridge over a gaping cavity at the bottom of which the lung may be exposed.

2. Bone Lesions

These lesions are of very grave importance in the later development of pleuro-pulmonary wounds.

They are extremely common, and all surgeons who have observed and treated pleuro-pulmonary wounds have insisted upon their gravity, a feature already recognised by the textbooks.

These bone lesions involve, in order of importance, the ribs, the scapula, the clavicle, and the sternum.

Fractures of the Ribs.—Sometimes the fracture is clean-cut, and there are even cases (bullet wounds) where the projectile has traversed a rib, making a punched-out hole in it, but this is exceptional.

Much oftener, especially when a projectile strikes the chest wall tangentially, there is a fracture, or rather a smashing-up of the bone, which is reduced to a mass of splinters. These are sometimes driven onwards, either into the lung or some distance into the chest wall, while other fragments, though still adherent at some point to the parietes, pierce and tear the lung substance.

These splinters, adherent or free, cause profuse primary hæmorrhage, and also secondary hæmorrhage by ulceration of the vessels which are in contact with them (Latarget).

Damage to the bones, sometimes extensive at the entrance-wound, is usually much more marked at the wound of exit.

This loss of bone substance results in keeping the

thoracic wound wide open. We shall see how grave is such a lesion, both immediately and secondarily, when it may be associated with infection which is often a fatal sequela of wounds which have a large external opening (see p. 769).

Fractures of the Clavicle.—These are rather frequent. Here again splinters may be driven into the apex of the lung ; more frequently, perhaps, the bone fragments injure the vessels at the base of the neck, and more often still damage the brachial plexus.

Fractures of the Scapula.—We have found these present in 10 per cent. of pleuro-pulmonary wounds. As Toussaint and Baumgartner in their earliest papers, and more recently Picqué and Dupérié, have said—an opinion furthermore accepted by all surgeons—fractures of the scapula constitute a factor of great gravity on account of the splintering of the bone, of which the fragments seem to " swarm " in the parenchyma of the lung. Further, grave damage to the scapula is always accompanied by subjacent costal lesions, and gaping wounds of this kind are extremely serious.

It may happen, however—and we have seen several such cases—that the projectile perforates the scapula, producing a hole with clean edges, as though made by a punch.

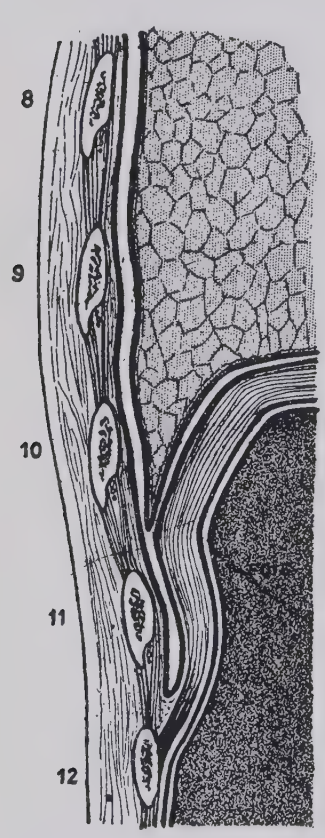
Fractures of the Sternum.—Though rarely reported, they are none the less interesting : we have found 3 per cent. amongst our cases. It seems to us that they are always serious, both from the loss of bone substance and from the inevitable result that the mediastinum is laid open more or less freely.

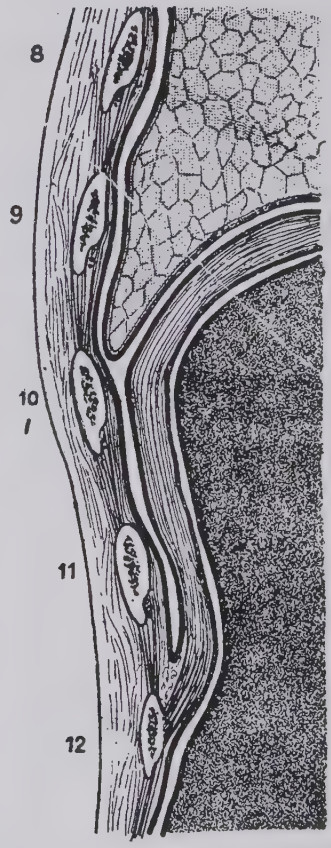
3. Pleural Lesions

The parietal pleura alone may be involved. These cases are far from being rare, and observations made during the present war confirm the opinion previously

expressed by Souligoux, who quoted cases by Panas and Polaillon, and the experiments made by Nélaton.

In some penetrating wounds the lung is entirely uninjured, the projectile falling somehow into the





FIGS. 1 and 2.—Vertical and antero-posterior sections of the thorax near the costo-vertebral groove. The two layers of the pleura are in contact both in inspiration and in expiration.

pleural cavity, but the uncomplicated type of pleural wound is more commonly instanced by seton wounds involving the lowest part of the pleuræ (see figs. 1 and 2).

These lesions are often extremely trivial, the serous

membrane showing very little evidence of the passage of the projectile; this is sometimes very difficult to discover with the naked eye. At the most there is a slightly reddened zone, with a small sub-serous hæmorrhagic patch, which indicates that a vessel has been divided, and even this is exceptional.

In simple transfixing wounds the aperture of exit from the pleural cavity may be overlooked during an examination made a few days later, unless the track from the cutaneous wound is followed inwards.

We have obtained evidence of the rapidity of repair in the serous membrane in wounded who have died after a few days from grave lesions of other organs.

Sometimes a thin fibrinous exudate, which is readily detached, may be recognised, but this exudate always indicates inflammatory reaction. *In aseptic wounds* the injured pleura, examined on the fourth or fifth day, has the macroscopic appearances of a normal serous membrane. Nothing distinguishes it from the neighbouring portions; it has the same slightly shiny aspect, and is sufficiently transparent to allow deeper structures to be seen.

The histological repair of clean-cut wounds of the pleura is rapid. Cornil has demonstrated experimentally the stages of its progress.

In a very short time, a sort of fibrinous bridge is formed, which reunites the severed tissues, provided they are almost in apposition, as is usual in the cases we are now considering. After about twenty-four hours the endothelial cells become swollen and multiply within the meshes of the fibrinous network. Thus the solution of continuity is very quickly restored. Beneath the surface the sub-endothelial tissue becomes filled with branched cells, which build up a new vascular tissue. In a few days repair is complete.

Injuries of the pleura in *open wounds of the thorax* are very different. In these, there is a real loss of substance of the serous membrane. In one of our

cases there was an opening in the parietal pleura into which the closed fist could be inserted without difficulty. This lesion is of two-fold importance. We shall see later that it influences the production of an hæmothorax, in which the blood, no longer in contact with an endothelial surface, tends to coagulate. And in addition, such injuries are irreparable by surgical means, because the inelastic parietal pleura is adherent to the endothoracic fascia, so that suture of the serous membrane becomes impossible.

In wounds with fractures of the bony thorax, splinters, etc., aseptic repair is the exception. And even when healing by first intention seems to be taking place, there is always a more or less marked inflammatory process, with exudation of fluid, which frequently forms false membranes and results in adhesions.

The formation of pleural adhesions, their causation and composition, cannot be studied apart from the associated pulmonary lesions; they will therefore be considered in the same chapter.

4. Pulmonary Lesions

The macroscopic characters of pulmonary lesions suggest a division of cases into three groups.

(*a*) The projectile has traversed the lung, making an in-and-out wound.

(*b*) The projectile after penetrating for some distance remains in the lung.

(*c*) The projectile or projectiles, and bony fragments which they have produced, have freely divided, lacerated, or even ruptured the lung.

(*a*) **Simple Pulmonary Wound.**—This transfixing wound is usually caused by a bullet, fired from a distance of 500 to 1,200 metres.

1. The wound may be clean, without intra-pleural hæmorrhage of any degree, and without pneumothorax.

There is no better description than that of Baudet, written some years ago: "On the grey and glistening surface of the lung there is a violet, ecchymosed patch, about the size of a franc-piece. In the centre of this zone is a small spot which is red in appearance; this is the pulmonary wound, the margins of which are often in contact when they have ceased to bleed; the hole made by the bullet will be found in the centre of this red spot."

The area of ecchymosis quickly fades, though sometimes it persists as an opaque depression upon the visceral pleura, and if the laceration has been of some size it will often produce, at a later period, a small fibrous cicatrix, of no great strength.

The intra-pulmonary track is also very quickly effaced, to such an extent that often it is impossible to recognise it, even after a few days. Healing of the margins of the wound and of the intra-pulmonary track is only possible when there has been a very small intra-pulmonary hæmorrhage, which is quickly reabsorbed.

2. When the in-and-out wound is situated in the middle of the lobe, or at the apex, and especially in the region of the hilum, there is always laceration of vessels; these, according to their size, will produce a hæmorrhage which may remain localised in the lung, or may extravasate into the pleural cavity. This hæmorrhage will often be accompanied by pneumothorax.

We shall study in detail the characters of these complications (see p. 709). Here we must be content with showing what influence they exercise on the pulmonary lesions.

The hæmorrhage, whatever its origin, and provided that the pleura is closed, will act like any other intrapleural effusion, and will compress the parenchyma of the lung as it increases.

The retraction of the lung begins at the lowest part

of the inferior lobe, the volume of fluid gradually pushes back this lobe, and the lung shrinks towards the hilum, which remains as a fixed point.

The action of the air set free in the pleural cavity is often added to this effect of the hæmothorax, and compression of the lung is still more aggravated by it.

The post-mortem investigations which we have been able to make in these cases, at intervals more or less remote from the incidence of the wounds, are interesting.

When the thorax is opened, effused blood is seen in all parts of the pleural cavity, and the lung is displaced towards the mediastinum. In the simplest and most recent cases, after removal of the fluid, it can be ascertained that the culs-de-sac are uninjured. They are covered sometimes with a thin fibrinous exudation, but fibrinous blood-clots are not found. We shall see later when and under what conditions these coagula are met with.

The same fibrinous exudation, sometimes inconsiderable in amount, covers the compressed portion of the lung.

The through-and-through wound is situated above the compressed zone, or at the level of this zone.

In the first case, its aspect is as previously described. The portion of the lung which seems to float above the liquid blood is rose-tinted in front, and bright red behind, over an area of variable extent which depends upon the amount of intra-pleural hæmorrhage. A deeper-coloured spot, a filamentous exudation, or a blackish red patch often marks the point of entrance and exit of the projectile.

When the orifice of entry is situated in the region compressed by the hæmothorax, it is sometimes most difficult to identify it upon the crumpled-up and collapsed lung. At times, however, beneath a thin fibrinous layer, which is readily detached, an open track may be found, into which a thick blunt-ended probe may be introduced easily.

If the compression is marked, and the lesion is several days old, *the margins of the track* may be adherent. Frequently they are covered with an exudate, grey with reddish lighter portions, a sort of fibrinous clot, which may, according to the calibre of the track, either fill it completely, or surround it like a sleeve.

If the parenchyma be incised along the track of the projectile, tiny particles of bone or shreds of clothing are sometimes found.

All round is a hæmorrhagic area of variable extent, which is always irregular in outline, and forms, so to speak, the *solid incompressible wall of the track.* In transfixing bullet wounds, the section is usually clean-cut and the hæmorrhagic zone is of slight extent. In transfixing wounds due to shell fragments, which lacerate the tissue, the resulting intra parenchymatous hæmorrhage is irregular, and often severe.

These hæmorrhagic areas visible to the naked eye are still more appreciable on palpation. The track of a projectile may thus be recognised on gentle manipulation between two fingers of successive areas of the lung, when a slight resistance is felt which, in contrast to the peculiar softness of collapsed lung, and to the sensation yielded by lung which still crepitates and can serve for respiration, is very characteristic.

An in-and-out pulmonary wound is rarely accompanied by serious hæmorrhage, except when it involves the region of the hilum. More frequently the track is seen to be studded with tiny localised hæmatomata, resembling nuclei of infarction. Hæmorrhagic zones or foci are sometimes found at a distance, but these are more frequent in "blind" wound tracks.

(*b*) **Blind Wounds.**—*Situation of the projectile.*—When the missile which has caused the wound, or bony splinters, etc., remain embedded in the lung, a sort of cavity is formed around it.

The site of this cavity varies, and may be in the

apex, hilum, base, some distance from the surface of the lung, or sometimes even in an inter-lobar fissure.

The cavity is visible to the naked eye when it is not

FIG. 3.—Portion of lung showing a blind wound due to a shell fragment.

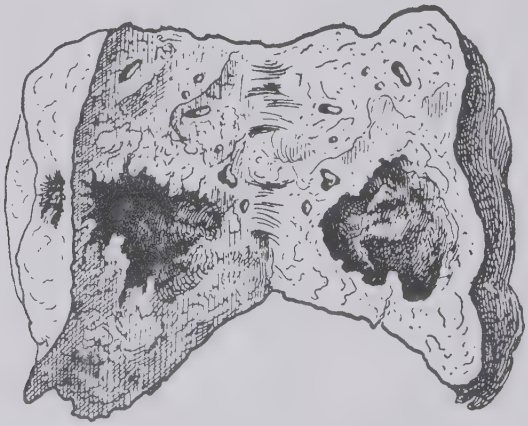


FIG. 4.—Same as Fig. 3. A section has been made to the right of the wound of entry, so as to expose the irregular cavity in which the projectile is lodged.

too deep. As it is not subject to the effects of compression, its presence may be guessed at from the surface, on which it causes a prominence, or an area of

deeper tint than the rest of the surrounding tissue. Marked resistance to the touch at once indicates the position of the embedded foreign body or bodies, surrounded by a zone of induration.

The track, which is usually straight, and has similar characters, leads to a cavity of variable size, which is moulded on the foreign bodies. These vary widely in character, and it is sometimes most surprising to find, some distance from the wound of entry, shreds of clothing, portions of equipment, small pebbles or gravel, splinters of bone, which have been carried in by the projectile, and have sometimes made a long track in the lung.

The interior of the cavity is covered by a thin fibrinous exudate, which is readily detached and beneath this the pulmonary tissue may be observed, furrowed with minute depressions limited by the framework of the vascular connective tissue. On pressure a scanty amount of blackish liquid exudes and a zone of diffuse hæmorrhage, irregular in contour, extends for some distance around it; this occurs sometimes in the form of nodules which leave between them less indurated areas. At the periphery there is no precise limit, no clear line of demarcation between the neighbouring tissues and this area, which appears as a series of stains or deeper-tinted patches, whose colour fades as the periphery is approached.

These hæmatomata, when they are a little older, acquire a compact blackish tint, quite comparable with the "truffle" nodules of infarction. Thrombosed vessels are frequently visible in these hæmorrhagic foci, as is well shown in Fig. 5.

Finally, at a little later period, the cut surface is dry, and the tissues are definitely indurated.

These hæmorrhagic foci are not confined to the injured region; they may be found at a distance, either in the same lung, or in that of the opposite side (Latarget). These distant hæmorrhagic foci, caused

by contre-coup, explain the existence of extensive hæmatomata in the lung some distance from the injured zone.

(*c*) **Extensive Laceration and Tearing of the Lung.**—Such lesions are rarely observed, as men so badly wounded usually die on the field. Nevertheless some cases have been reported, and P. Duval quotes a case in which the upper lobe was cut in half.

In other cases the lung is torn to pieces or pulped.

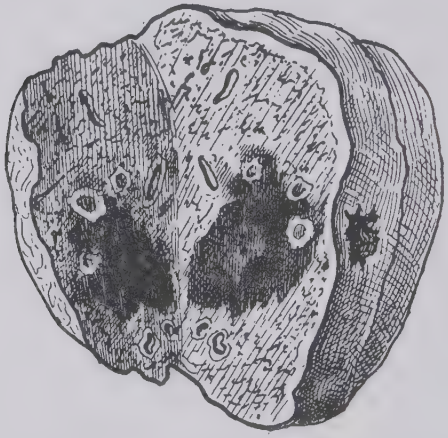


FIG. 5.—Same as Figs. 3 and 4. The section is made to the left ofthe orifice of entry. The shaded area represents the hæmatoma which forms the wall of the cavity containing the projectile. Thrombosed vessels are clearly visible in the middle of this hæmatoma.

The parenchyma, infiltrated with blood, resembles a sponge torn to rags, and its framework of vascular connective tissue alone retains any continuity of substance. In a soldier who only lived two hours, a large hæmatoma occupied the anterior surface of the left upper lobe; in its centre was an opening 5 centimetres wide, which was bridged by lung tissue, and led into a cavity the size of an orange, where the lung was completely pulped. This was caused by an in-and-out bullet wound.

HISTOLOGICAL LESIONS

We shall study in turn the track of the projectile, its resting place, and the changes associated with great losses of tissue.

Track of the Projectile.—Latarget has described the lesions in wounded who have rapidly succumbed to their injuries. These lesions are disposed in three concentric zones.

The first, or most internal, forms, so to speak, the wall of the track; it shows extensive tissue destruction and along its free margins the contours of the alveoli have disappeared, and the vessels and the bronchi are seen to be torn by the passage of the projectile. Beyond this, the contour of the alveoli can be recognised, but indistinctly, as though they were collapsed, and they contain, strange to say, no blood elements in their interior. This internal zone is limited in width to a few millimetres.

The second zone is characterised by very abundant hæmorrhage; in this focus of infarction, the alveolar contours are indistinct, owing to blood infiltration; in the middle of this area of contusion, here and there are found faintly outlined lacunæ of emphysema.

The third, or zone of peripheral emphysema has no definite limits, passing by insensible transition from the area of infarction to an excentric zone, characterised by the absence of hæmorrhage, and by the confluence of alveoli whose intermediate walls have disappeared.

We have examined post mortem the lesions caused by injuries some days previously and they are quite different. The loss of substance, of however great an extent, is always surrounded by a hæmorrhagic zone, forming a more or less extensive hæmatoma, which, first tearing, and then infiltrating the parenchyma, constitutes the fundamental lesion of pulmonary wounds.

(*a*) *The wall* of the track, which forms the inner-

most zone, is always lined by a fibrinous exudate, adherent to the pulmonary tissue, the elements of which can no longer be distinguished; the base of the exudate is marked by a more or less abundant infiltration of round cells.

(*b*) Immediately outside, and overlapping the fibrinous exudate, is a *hæmorrhagic zone*. This is more or less extensive, usually irregular, and infiltrates the pulmonary tissue excentrically. In it the alveoli are burst open: their contours, irregular and indistinct, are recognisable solely by some fibrillæ which show up when stained by orcein, in the midst of the blood which infiltrates all the normal elements. Then gradually the alveoli reappear, packed with red cells.

(*c*) Beyond this, the pulmonary tissue, unless it has been compressed, has a normal appearance; its alveoli show sometimes a thin albuminous exudate with a small number of wandering cells (see Fig. 6).

In one case in which a bullet had passed obliquely, in and out of the left lung in its antero-inferior part, there was around the track a zone completely infiltrated with blood, then an area where the alveolar contours were clear, but the alveoli themselves were filled with an albuminous exudate, and lastly a third peripheral hæmorrhagic zone.

Cavity in which the Projectile is lodged.—The same fibrinous exudate covers the walls of the cavity, which are irregular, uneven, and sometimes present all kinds of pockets, caused by foreign bodies, bone splinters, or fragments of metal which have stuck in the loose tissues. Sometimes a divided bronchus, blocked, when it is of small calibre, by the fibrinous exudate, may be seen in the cavity. Here the peripheral hæmorrhage is always more diffuse, more marked, and more extensive. A peculiar characteristic of the hæmatomata around these cavities is that they are composed of a series of foci; these are compact at the

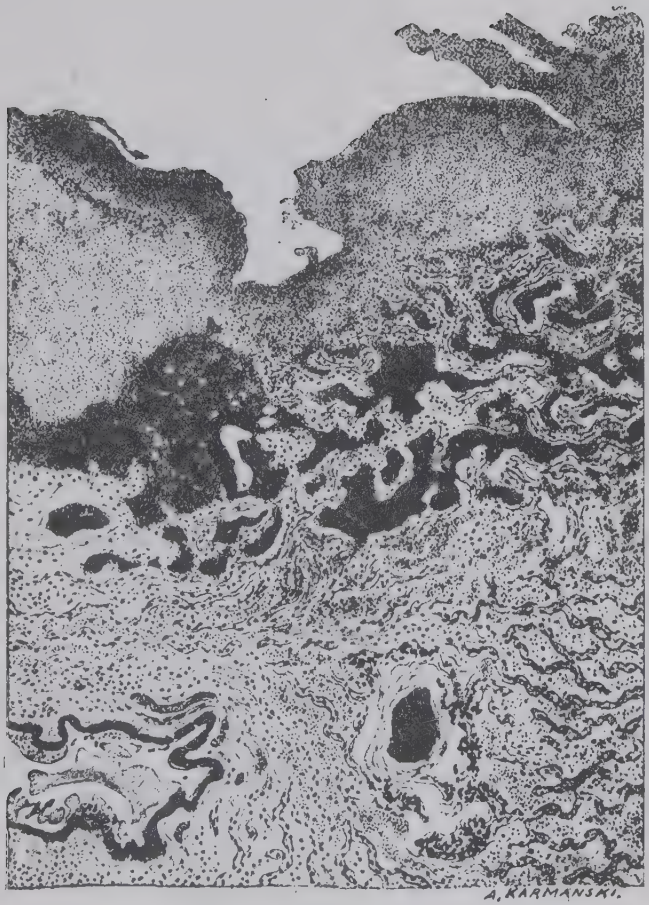


FIG. 6.—Through-and-through (seton) bullet wound of lung. The upper portion of the section shows a fibrinous exudation which completely lines the track. Beneath is a hæmorrhagic zone; on the left this forms a patch in which it is impossible to recognise any lung tissue; to the right, on the other hand, the blood has not completely broken up the alveoli, although it has displaced them; some structures have proved more resistant. In the lower part of the section, compressed alveoli gradually give way to those which are normal in form. A bronchus and a pulmonary arteriole are also seen in section.

centre, and interspersed between them are zones in which the blood infiltration is less well marked. Fig. 9 gives a diagrammatic view of this appearance.

The serious and destructive lesions produced by

FIG. 7.—A section of one of the hæmorrhagic patches shown in Fig. 9. Above and to the right blood quite fills the alveoli, whose distended outlines may be distinguished, but gradually the hæmorrhagic exudation has produced less effect, and simply infiltrates the walls of the alveoli, which appear flattened and spread out.

hæmorrhage, at the point where the laceration occurs, are seen to diminish gradually at a distance from the walls of the cavity.

Fig. 7 was drawn from a preparation of one of the

hæmorrhagic foci represented in Fig. 9. It demonstrates how the blood which entirely fills the alveoli on the right-hand portion of the section, where many of them are ruptured, gradually infiltrates the sub-

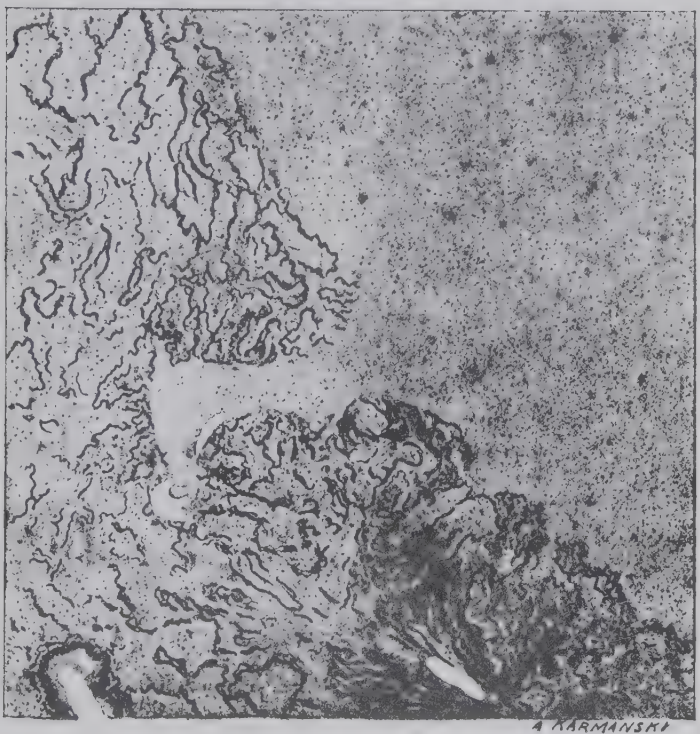


FIG. 8.—Section, stained with orcein, through a pulmonary laceration with severe intra-parenchymatous hæmorrhage. Above and to the right is a cavity filled with blood; to the left, the lung is compressed; the elastic fibrillæ are stained black and show well the amount of compression exerted upon the alveoli.

jacent tissue, the well-preserved structure of which can be perfectly distinguished.

Laceration of Tissue.—Rupture of Parenchyma.—In such cases, traumatism may be translated into hæmorrhage, and more or less extensive loss of substance. The result is sometimes shown by the lesions illustrated in Fig. 8.

This section has been stained by orcein to demonstrate the importance of the elastic fibres. The lung has been ruptured, and the loss of substance has been followed by hæmorrhage, which most certainly has been sudden and violent. This has then acted mechanically, compressing the parenchyma, the elastic tissue of which is seen to be crushed together and flattened out, so as to form a kind of barrier to the

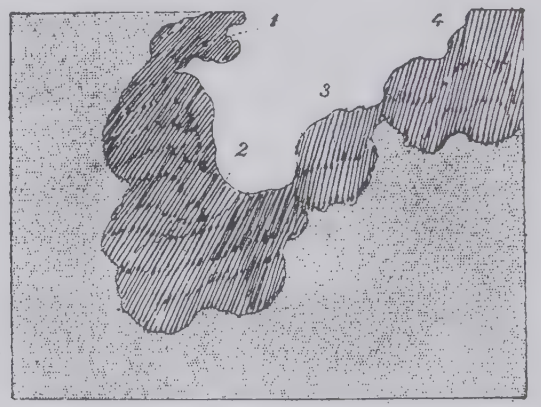


FIG. 9.—Diagram, slightly enlarged, to show the irregular nodular form of the hæmatoma around the cavity. Nos. 1–4 represent hæmorrhagic foci around the site of the projectile.

intra-alveolar blood infiltration, which is extremely small in this region.

Such are the peculiar characters which intra-pulmonary hæmorrhage may present, but the injuries of the lung do not stop there.

Associated Pulmonary Lesions

Some, of a purely mechanical order, are the result of the compression exercised by a hæmothorax upon the lung — such as *pulmonary collapse* with which is sometimes associated *atelectasis* or *pulmonary carnification*,[1] others are by nature or appearance

[1] These two terms, pulmonary collapse and atelectasis, are too frequently confounded; they correspond to quite different histological conditions.

inflammatory, and are usually localised around the hæmorrhagic foci.

Pulmonary Collapse.—We have seen that, macroscopically, the compression of the lung may appear to be total, but more frequently it is limited, and usually only affects the inferior lobe. Post-mortem the lung when stripped of the false membranes which sometimes surround it, and if there is no organised exudate on its surface, appears flabby, soft, and of a greyish tint, though its outer surface is darker from infiltration with blood.

The alveoli contain no air, and the pulmonary

FIG. 10.—Section of a collapsed lung. On the surface the pleura is thrown into folds; beneath this the pulmonary alveoli, whose elastic-tissue walls are stained black, are compressed and flattened out. Air and blood can circulate no longer.

vessels no blood. The lung does not crepitate under the pressure of the hand, but it can be insufflated. Only certain portions, where a hæmatoma has been caused either primarily or secondarily, maintain a consistency which suggests pulmonary induration. The collapse is often more marked than that which is seen in primary tuberculosis of the pleura with great effusion, and the histological appearances do not differ in any way from descriptions of this condition given in

textbooks. Beneath the wrinkled external pleural surface, the alveoli are crowded together, and flattened, with their cavities reduced to linear slits; the empty capillaries are no longer visible. These appearances are well shown when the tissues are stained with orcein; the crowding together is marked, until the hæmorrhagic foci are reached, which remain incompressible (see Fig. 10).

Atelectasis.—Carnification.—In some cases we have seen upon the surface of a collapsed lung a fairly exten-

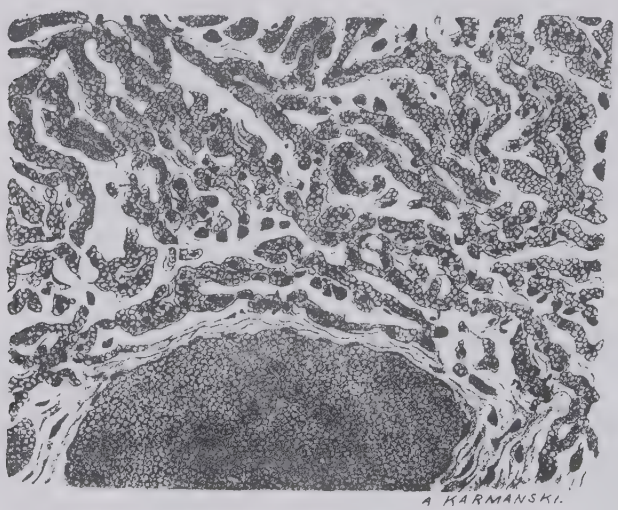


FIG. 11.—Atelectasis.—The capillaries are distended, and the lumen of the alveoli is greatly reduced, often even obliterated; at the lower part of the slide a vessel filled with blood is seen.

sive zone, violet-red in colour, flaccid, without elasticity, and of a consistency resembling muscle. Under the microscope, the section shows flattened alveoli, while on the contrary the capillaries, distended with blood, appear swollen. The cells of the alveolar epithelium, are voluminous, and project into the cavity (see Fig. 11). The vessels are filled with blood. These are the histological appearances of atelectasis

or pulmonary carnification. It is acknowledged that, for the production of such a lesion, the bronchus which serves the atelectasised portion of the lung must be obliterated; in some cases this may be due to compression, though it is more often caused by a blood-clot.

Peri-hæmorrhagic Lesions.—Sometimes around the tracks, or around the cavities which contain foreign bodies, or around pulmonary lacerations, deep red coloured zones of lung tissue are met with; they are ill-defined and fairly firm to the finger, so that they resist the compression of the extravasated blood. From the cut surface of the section a scanty reddish exudate escapes, and the lung does not crepitate, and when placed in water barely floats, or may sink beneath the surface.

Relying upon this aspect of the surface itself, many observers conclude that these lesions show hepatisation, and "*traumatic pneumonia*" is spoken of as a common occurrence.

It seems to us that possibly they have allowed themselves to be guided by theoretical considerations. It is well known, as a classic observation, that around Lænnec's foci of hæmoptoic infarction, hepatisation either pneumonic or broncho-pneumonic develops and this may go on to suppuration, and even to gangrene. Undoubtedly such processes may take place around the foci of traumatic hæmorrhage, inasmuch as these often enclose septic foreign bodies. These cases will be studied later. But the condition of secondary infection which most frequently appears to be the cause of the hepatisation, which sometimes complicates the infarcts of Laennec, is not found in traumatic hæmatoma. The two lesions are not comparable, either in their pathogeny or in their evolution. To state that the greater number of penetrating wounds of the lung are complicated by pneumonia or broncho-pneumonia around the injured area, is to

make an assertion which cannot be verified by pathological evidence.

The lesions met with around the hæmorrhagic foci are rather of the nature of congestion. Sometimes quite extensive areas which present all the characters of *pulmonary splenisation* are visible. The perfectly distinct alveoli contain shed endothelial cells, in varying numbers, mingled with leucocytes and red corpuscles but without fibrinous reticulum or organised exudate. The walls of the alveoli are often enlarged and their capillaries distended.

We have never been able to verify the presence of a true pneumonic "block" around the hæmorrhagic foci.

In one case we observed a distinctly peculiar histological condition :

The lesion was eight days old : a piece of shell had traversed the base of the right lung, and had emerged at the level of the last rib after passing through the liver. There was an extensive hæmorrhagic focus in the lower lobe of the lung. Around this focus, and extending some distance into a compact violet-red zone, areas in which the lobules were packed with red corpuscles were visible under the microscope. These alternated with other patches in which endothelial cells, capillary walls, and connective-tissue framework had begun to proliferate, and to form true cellular outgrowths which completely filled the alveolar cavities. A light fibrinous framework supported this peculiar new formation, which at certain points had some features in common with the lesions described by Cornil and René Marie in experimental traumatic pneumonia. But it must be stated that these alveolar lesions are not uniformly distributed, and do not form a "block" extending over a whole lobe.

Associated Pleural Reactions. False Membranes. Adhesions. Clot.

False Membranes.—We have already shown that the spot at which the covering endothelium of the parietal pleura has been injured is marked by a fibrinous exudate. The same exudate is found upon the visceral

pleura, where it forms a sort of fibrinous plug in the pulmonary wound.

Spread out like a delicate veil, thin and friable, it often covers the lung with a light false membrane, which is scarcely adherent, and passes over the folds formed when the lung is compressed.

This exudate indicates the degree of reaction of the serous membrane. When a hæmothorax remains aseptic in a closed thorax, this reaction is very slight; the fibrinous veil does not become organised, and is reabsorbed as the lung resumes its functions, and finally entirely disappears.

Often, however, the serous membrane reacts, and when this happens it is always the result of an infection, either local or contiguous (costal osteitis, for example). Not every pleural infection ends in suppuration, which may be absent, but it is precisely in these cases of attenuated infection, often of prolonged duration, that the serous membrane proliferates and false membranes form with a rapidity which is sometimes surprising. The pleuræ thicken, filamentous bridges are thrown from the visceral to the parietal pleura and these fragile, slightly resistant bridges form partitions across the pleural cavity. They are at first like slender "spider's webs," to use Letulle's apt simile; then a vascular connective tissue quickly replaces the fibrin which served at first as scaffolding for the false membranes, and organised adhesions form. They occur chiefly on the lateral surfaces and at the bases of the lungs, where they may fill up the phrenico-costal sinus. Sometimes they are limited, either to an interlobar fissure, or to a point on the surface of the lung; where a subjacent projectile excites and localises the proliferation of new membranes.

Sometimes a large clot is found in the middle of these adhesions or false membranes; at first it is red, but may become later of a greyish-white colour, and is apparently deprived of every single red corpuscle;

usually it is soft and flaccid, and soaked in a liquid of mucoid, almost gelatinous appearance, at other times it is more compact. It lies free in the pleural cavity, and has no connection with the false membranes and forms no part of them.

When the adhesions are extensive, they are not readily absorbed, and a pleuro-pulmonary union of varying extent is formed; this is especially frequent at the bases, but may be found in the main cavity, and is sometimes localised to the apex; we shall return to these pleural adhesions in a later chapter.

PNEUMOTHORAX

Pneumothorax, or escape of air into the pleural cavity, is a complication which results fairly constantly from chest wounds. However, it only becomes important when the volume of air which escapes is sufficient to interfere with the expansion or induce the collapse of the lung and reduces its oxygenating capacity. It becomes a complication of special gravity if the intra-pleural pressure is so increased as to interfere mechanically with the mediastinal organs and the great vessels of the heart.

Moreover, it appears to be quite exceptional in chest wounds that pneumothorax is present alone. Nearly always effusion of blood is added to the escape of air into the pleura. It is difficult to conceive a parietal or pulmonary wound large enough to allow air to escape which would not at the same time involve a vessel of sufficient size to allow blood to extravasate.

In a great number of cases equilibrium is established between these two effusions; the escaped air is absorbed much more readily than the blood.

In this way we may interpret the varying statistics, which appear so widely divergent at first sight. Piery found pneumothorax in 47 per cent. of his cases.

Picqué and Dupérié reported 62 per cent., while Maillet only met with 6·2 per cent. These variations are easily explained when the period at which the case is examined is taken into account. Pneumothorax clinically perceptible at the outset, but of slight importance, rapidly disappears by absorption. In fact, Picqué and Dupérié, who found air in the pleura in 62 per cent. at the outset, after a few days only found 7 per cent. of uncomplicated pneumothorax. This gives a figure practically equal to that reported by Maillet.

The entry of air into the pleura may take place in different ways. We quote as exceptional a case in which the autopsy disclosed a wound of the trachea from which air escaped direct into the left pleura.

Pneumothorax is produced either by injury of the lung, or perhaps more frequently by a parietal wound.

It is obvious that a wound of the pulmonary parenchyma of exceptional extent is required for air to pass into the pleura in sufficient quantity to become serious. Let us turn to the lesions made by a projectile when traversing a pulmonary "tongue" or the periphery of a lobe. No important bronchus has been implicated, or at least no air-carrying tube which has a cartilaginous skeleton of sufficient strength not to be crushed, either by the projectile itself, or at least by the intra-pulmonary hæmorrhage which, as we have seen, is set up rapidly all around the track.

Moreover, we have experimentally made incisions of varying depth into the pulmonary parenchyma of the dog, without having been able to recognise the passage of air through the wound, unless it were in the region of bronchi of the third division, which are of course very deep.

On the other hand, the parietal wound, unless it happens to be unusually oblique, readily allows air to enter the pleura, especially if the projectile has struck the chest during an inspiration. It will be understood

that we are not speaking here of cases in which the wound is so extensive as to allow free passage of air in both ways.

From whatever source air may have escaped into the pleural cavity, the mechanism by which it is produced can exert a marked influence upon the clinical features to which it gives rise.

When air has entered the pleural cavity by an orifice of some size, but the margins of the wound are such as to allow of its rapid closure, the quantity of air remains limited, and very small; the intra-pleural tension is slight, so that this air will be rapidly absorbed. *Closed pneumothorax* is the most frequent and also the most benign type.

When the parietal wound is large enough to allow air to enter and leave the pleural cavity, the pneumothorax is termed *open*. The air is renewed in currents of varying volume, according to the dimensions of the external opening, and this continual to-and-fro movement is accompanied by an actual dance of the lung, which literally jumps in the chest at each respiratory movement, and may even appear at the parietal wound during expiration, causing a pulmonary hernia. A third type of pneumothorax must be considered here; this is often extremely serious, owing to the compression which it induces; this is called *pneumothorax by hyper-pressure*, valvular pneumothorax, or *suffocating pneumothorax*.

Here, the air can readily enter the chest, but the aperture of entry is so arranged that the air cannot escape. During inspiration a certain amount of air enters the pleural cavity, but during expiration it cannot pass out by the orifice, whose lips form a flap or valve. The pressure exerted on the external surface of the lung therefore increases the respiratory difficulty and instinctively the wounded man takes the next inspiration more deeply. Air enters again without being able to escape, the pressure is further increased,

and this goes on until compression of the mediastina, displacement of the heart, and interference with venous return, end in death from asphyxia.

It must be noted, that when accidents of this kind occur, the whole pleural cavity is filled with air, and for this to be possible the lungs and pleura must be absolutely normal. The pneumothorax is then *total*.

When, as frequently occurs, anterior adhesions have limited the dimensions of the pleural cavity, air can only occupy a certain zone of the serous cavity, and the pneumothorax is *partial*. In these cases it is quite exceptional for it to assume sufficient severity to need the attention of the surgeon.

HÆMOTHORAX

One of the most frequent results of pleuro-pulmonary wounds is the effusion of blood into the pleural cavity.

Hæmothorax is usually limited to one side; there are, however, several cases of double hæmothorax recorded (Petit de la Villéon, Picqué and Dupérié). We have seen such cases ourselves. But in those who have survived, the effusion has been trivial, at least on one side.

Origin of the Blood.—The blood, as we have already seen, may come from the chest wall or from the pulmonary parenchyma. Very rarely, the hæmothorax originates from vessels of neighbouring organs; such as those of the liver, or at the root of the neck, etc.

Hæmothorax from Wounds of Vessels of the Parietes.—This was looked upon as rare (Souligoux); in fact, it is necessary that a vessel such as the intercostal or internal mammary artery must be involved to cause a serious effusion of blood. Injury to an intercostal artery is scarcely ever produced without a fracture of a rib. This is almost essential for a lesion of the intercostal in its median portion where it lies hidden in the costal groove. Souligoux has shown

that if this artery is opened, it ought to bleed readily into the pleural cavity, for it is immediately subpleural, and only separated from the parietal pleura by a few fibres of the internal intercostal muscle. The intercostal artery in its posterior portion is more vulnerable. The internal mammary, and especially the accessory internal mammary artery, which descends vertically on the antero-lateral wall of the thorax, and cuts perpendicularly across the intercostal spaces (Souligoux), may be the source of hæmorrhage which formerly was looked upon as very serious. This has not appeared to us a frequent source of hæmothorax.

Injury to a vessel of the parietes by a projectile causing an in-and-out wound should not be considered exceptional, especially when a rib is fractured and an opening of some width into the thoracic cavity exists.

Hæmothorax from wounds of vessels of the diaphragm are infrequent, but worthy of notice ; we have seen two cases.

Hæmothorax of Pulmonary Origin.—This is the most frequent cause of hæmorrhage, which is only really profuse when vessels of medium calibre are involved. Nélaton thought that only vessels which accompany bronchi of the second or third order could give rise to severe hæmorrhage, and that branches of greater size bled too profusely for the patient to survive. This opinion is certainly too dogmatic, but it corresponds nevertheless to the average experience.

The calibre of the vessel is only one factor ; the *weapon of traumatism* is of great importance. A bullet may traverse a pulmonary lobe without producing any hæmorrhage. A piece of shell with ragged edges, frequently carrying with it metallic fragments, spicules of bone, etc., may wound the lung in the same region, and cause *diffuse hæmorrhage from the whole surface of the wound* by injuring numerous small vessels.

The situation of the vessel involved is important.

A clean section of lung substance, near the anterior or inferior border, cannot give rise to hæmorrhage. We have been able to convince ourselves of this, when endeavouring by experiments on dogs to produce hæmothorax of pulmonary origin. Section by scissors of the inferior lobe over an area of 5 centimetres did not yield a drop of blood. The lung retracts with extreme facility, and its elasticity thus ensures hæmostasis.

Wounds of the base bleed less than those of the apex, in particular than those of the hilum, which invariably are followed by profuse hæmorrhage.

Hæmorrhage from wounds of the hilum may be uncontrollable at the outset, and cases which survive do so only for a relatively short time.

Cases, however, occur in which hæmorrhage is *delayed*, others in which it comes on slowly and gradually as a continuous oozing. These phenomena explain the gradual formation of a hæmothorax which occurs during the period immediately following the injury.

The quantity of blood which accumulates in the pleural cavity is rarely very considerable, and not to be compared to the volume of some sero-fibrinous effusions. In cases which reach a hospital the quantity of blood in a closed pleural cavity rarely exceeds a litre and a half to two litres ; even this amount, indeed, is very exceptional, and also very badly tolerated. The average quantity is from 1,200 to 1,500 grammes. Often it is less, varying between 800 and 1,200 grammes.

We are, of course, only dealing with effusions in a closed thorax during the period immediately following the injury, and are not referring to exudates due to the reaction of the pleura, which may appear later.

The most important factor in the arrest of pulmonary hæmorrhage is the pressure exerted upon the lung substance by the hæmothorax. This pressure is more effective when the lesion is situated in the lower

lobe. The compressed vessels rapidly thrombose (see Fig. 5).

Pleural adhesions so commonly present [1] also play a part in arresting hæmorrhage by localising the effusion. On the other hand, complete union of the visceral and parietal pleura is more likely to occasion diffuse intra-pulmonary hæmorrhage, or, in the case of an open wound, external hæmorrhage which is frequently profuse.

Pathological Physiology of Hæmothorax

Problems of great interest and complexity are involved in the study of hæmothorax.

Blood removed from the vessels and from the influence of the physiological processes which preserve its vital condition and function must inevitably undergo profound changes. When enclosed in a serous membrane whose structure is different from that of the walls of a blood-vessel, it constitutes a foreign body which the organism must endeavour to eliminate—it is a singularly complex foreign body, whose constituent elements, before being definitely eliminated or transformed, do not remain inactive, but exert an effect both on the serous surface surrounding them and on the organism in general.

We must now study the reaction of the pleura to the blood in contact with it, the effect on the blood of contact with the pleura, and the results of these two reactions, following them through the successive stages of a hæmothorax. The changes which occur are influenced and controlled by several factors of varying importance.

This investigation will be based upon two principal factors which, it seems to us, have hitherto not been

[1] In a large number of post-mortems conducted by one of the authors during a period of great activity, on cases who had succumbed to wounds of various kinds, old pleural adhesions were present in 30 per cent.

sufficiently taken into account; these are the stages at which firstly the formation, and secondly the infection (if any) of the hæmothorax, take place.

Recent Aseptic Hæmothorax in a Closed Thorax.—Constitution.—What changes occur in blood which escapes into the pleural cavity?

An examination during the first twenty-four or forty-eight hours of its constituents shows:

Red corpuscles roughly equal in number to those in the circulating blood; *e.g.* 4,681,000; 3,009,000 (Cases I and III of Dupérié); we have made similar counts.

Their appearance (size and staining properties) is apparently not modified in any way.

White corpuscles in considerable, though varying, numbers; these will be described in detail later (p. 725). Their appearance is approximately normal.

Chemical analysis of the serum has given us the following results, which correspond closely to those of Dupérié:

Analysis of fluid aspirated from a hæmothorax on the twelfth day:

Density at 12° C.	1·020.
Reaction	Feebly alkaline.
Extract dried at 100° C.	62·9 grammes per litre.
Mineral salts	10·2.
Sodium chloride	6·9.
Phosphates	Traces.
Carbonates	Present in small quantity.
Hæmoglobin	11·57 estimated as iron.
Urea	0·15.
Bile pigments	Absent.
Globulin	Traces.
Serine	Abundant.

Dupérié estimated the cholesterin in several cases of hæmothorax, and found amounts varying between 0·58 and 1·10 grammes per litre.

But if 10 or 20 cubic centimetres of fluid aspirated from a hæmothorax are left in a test-tube until the solids are precipitated, a very peculiar phenomenon is observed. The red corpuscles are precipitated, and in the great majority of cases the supernatant serum, which is of a dark-red colour from dissolved hæmoglobin, does not coagulate. These phenomena have been the subject of numerous discussions and call for further investigation.

I. Is the Fluid of the Hæmothorax coagulable or not?—What are the factors governing coagulability of blood in the pleura?

Opinion on this subject appears to be sharply divided, more particularly because available data are sufficiently definite to suggest conclusions. Some authorities, having aspirated the pleural cavity and obtained fluid which rapidly coagulates, draw the corresponding general conclusion, which is supported by the experiments of Trousseau and Leblanc, Nélaton, and G.-A. Bartoli, and corroborated by observations of which there can be no question, made during operations and post-mortems.

Others, however, are equally positive in declaring that they have obtained incoagulable fluid (Tuffier and Milian, Sacquépée, Mercadé, Laurens and Darcanne, Patel and Leriche, etc.). Lastly, eclectic opinion attempts to reconcile the opposing schools by taking the view that the blood coagulates in the pleural cavity, and that the fluid which is withdrawn is the serum which transudes from the clot while it is churned up by the respiratory movements, and therefore does not coagulate.

These contrary opinions rest upon incontestable facts which are not mutually exclusive, and we can readily understand, by following the evolution of a hæmothorax, why the fluid obtained may or may not be coagulable.

Blood coagulates in the pleural cavity for two reasons.

In the first place when the continuity of the endothelial lining is interrupted over too great an extent, as occurs in widely open wounds of the thorax, or with extensive parietal lesions, coagulation occurs. The blood also coagulates when the pleura is infected.

Here clotting is associated with the fibrinous reaction of the inflamed pleura. The infection may be slight and may not result in suppuration, but the fibrin formation acts as a starting-point for the precipitation and constitution of the clot, by supplying the necessary fibrin.

On the other hand, a recent and aseptic hæmothorax in a closed pleura does not coagulate in situ, *and remains incoagulable if withdrawn by aspiration.*

1. *The fluid remains uncoagulated in the pleura.*—Experimental and post-mortem observations confirm this assertion. Several autopsies on cases which had died during the first week have supplied examples of an aseptic hæmothorax in a closed thoracic cavity in which the fluid was uncoagulated, and no traces of a fibrinous clot could be discovered. At the most there was sometimes a light fibrinous reticulum on the pleural surfaces, but this was a thin and delicate structure in no way comparable to the clot of coagulating blood.

When a hæmothorax is produced experimentally in the dog by diverting blood from the axillary artery into the pleural cavity by means of a cannula coated with paraffin wax, thick, black, fluid blood, slightly viscous, but showing no trace of a clot, is found in the pleural cavity five hours after the operation. This experiment must be carried out aseptically, because the introduction of organisms provokes an inflammatory reaction of the pleura which is likely to cause intra-pleural coagulation. It was doubtless through their being unable to take such precautions that Trousseau and Leblanc concluded that blood coagulates when effused into the pleural cavity.

The objection might be raised that this fluid is no longer blood, correctly speaking, but only a dilution of red corpuscles in pleural fluid.

In the first place, however, red counts made as soon as possible have given us figures which are approximately normal, in the neighbourhood of four million red corpuscles per cubic millimetre, figures which we find confirmed by those of Dupérié.

The chemical composition of the fluid (see p. 713) also varies only slightly from that of normal blood plasma.

Does this fluid remain uncoagulated indefinitely? If it remain perfectly aseptic, we may confidently assert that it does. Even later, when its composition is altered by the addition of a fibrinous exudate secreted by the pleura, and this exudate undergoes the same changes as those which take place, for example, in sero-fibrinous pleurisy, the fluid remains in the pleural cavity without coagulating.

2. *The hæmothorax fluid is incoagulable, and remains incoagulable outside the pleural cavity.*

A short interval must expire before the blood effused becomes incoagulable.

In cases which we have been able to aspirate at an early stage, though never within the first sixteen or eighteen hours of their being wounded, the fluid was incoagulable. On the other hand, in cases where hæmorrhage into the pleura had not ceased, the aspirated fluid coagulated like fresh blood from a vessel.

Blood withdrawn by aspiration from the pleura of a dog ten minutes after an experimental hæmothorax had been produced coagulated almost immediately. This experiment was repeated half an hour later, and the blood still coagulated, although forty minutes had elapsed since the blood had escaped from the vessels and come into contact with the pleura. On the other hand, when some of the fluid was withdrawn four or five hours later, it was found to have become incoagulable.

These facts have an important practical application.

Blood, which has remained in the pleura a sufficient length of time to become incoagulable if withdrawn into a test-tube, may remain in the thorax indefinitely without showing any signs of clotting. *Incoagulability is permanent.*

Does this incoagulability persist throughout the evolution of the hæmothorax? As a rule, it terminates with the first stage, which may last eight, ten, or fifteen days. We have seen a number of cases of hæmothorax in which the fluid withdrawn was incoagulable until a long period had elapsed. In two cases the incoagulability persisted throughout the

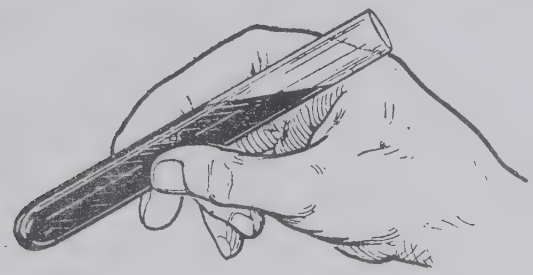


FIG. 12.—Incoagulable fluid.

evolution of the hæmothorax, which lasted, respectively, two and a half and three months.

The usual rule is that, at the end of a period varying with the nature of the case, the pleura reacts, secreting a fluid which mixes with the blood already present. The hæmothorax is, in fact, complicated by exudative pleurisy.

Fluid aspirated is seen to contain a fibrinous network, slight at first, but later more abundant, and when pleural exudation is rapid, coagulation may be rapid and complete.

In other words, the hæmothorax, the volume of which is often already greatly reduced, is complicated by a sero-fibrinous pleurisy.

An absolute and categorical assertion which our

chemical and experimental investigations have verified is the following :

A recent aseptic hæmothorax in a closed pleura, the endothelial lining of which is practically intact, does not coagulate in the pleura, and remains permanently incoagulable outside the pleural cavity.

The next step is to investigate the cause of this incoagulability.

It has been suggested that the endothelium of a serous cavity plays the same part in relation to the blood as does the endothelium of the vessels. This may be the explanation of the fact that the fluid does not coagulate in the pleura when the endothelium of the latter is uninjured and no bacterial infection occurs. But it does not explain why the fluid remains incoagulable outside the pleura.

It has also been suggested that the fluid is only serum transuded from a clot formed in the pleura ; we have shown that this is not so.

Now incoagulability is only developed after the blood has been for some hours (five hours at least) in the pleural cavity. What are the changes which take place in this interval ?

In spite of a large amount of work by physiologists on the normal coagulation of the blood, there is still an obscurity about this important subject which modern research has been unable to dispel. In the light of recent discoveries we have attempted an investigation of the cause of permanent incoagulability in hæmorrhagic pleural effusions without as yet any measure of success in solving the problem.

Clot is the result of the precipitation of fibrin in the form of a network of white threads in which the blood-cells are involved and enclosed. Fibrin may be formed in plasma from which the red corpuscles have been separated by decanting after the addition of sodium sulphate. There exists therefore in the plasma a substance capable of producing fibrin. This is fibrinogen.

The formation of fibrin from fibrinogen has been studied extensively for the past fifty years.

According to theories and hypotheses hitherto generally accepted, the formation of fibrin from fibrinogen is due to the action of fibrin-ferment, or thrombin.

Further, this ferment only exists in the blood in the form of pro-thrombin, or thrombogen.

"The whole process of coagulation therefore depends upon the transformation of thrombogen into thrombin, the latter then producing a corresponding change in the fibrinogen" (M. Bloch).

Calcium salts are indispensable to the formation of thrombin from pro-thrombin. Leucocytes, and nearly all body tissues, contain thrombokinase, a substance capable of activating thrombogen.

The blood of vertebrates therefore contains all elements necessary for the formation of a clot, but no clotting occurs.

As Et. Brissaud observed, the problem of coagulation would involve the organism in a peculiar dilemma if it were bound to choose between two opposite and equally urgent necessities—viz. keeping the blood in the circulation fluid, and the arrest of hæmorrhage in the event of injury. The fact of the matter is that the organism itself does not control coagulation: it merely provides coagulable blood, and external physical agencies do the rest.

It might therefore be suggested that there is a substance in the circulating blood, hitherto undetected, which plays the part of an antithrombin, and inhibits the action of thrombokinase on the pro-thrombin; which, in other words, prevents the initial step in a series of changes whose final result is the formation of a coagulum.

It is these various changes that we have tried to detect or to reproduce in hæmothorax fluid.

Apparently the cause of incoagulability is unconnected with the absence of the thrombokinase required for activating the pro-thrombin. If equal quantities of hæmothorax fluid and tissue extract (extract of liver or muscle) are mixed in a test-tube, no signs of coagulation appear, and the liquid remains, as before, incoagulable. Nor is fibrinogen lacking, a fact which is proved by the following experiment. If one volume of fresh normal blood is added to two volumes of

hæmothorax fluid, the resulting liquid does not coagulate, although the fresh blood must obviously contain fibrinogen. Nor is it due to the absence of calcium chloride. Analysis shows that the saline content is higher than in normal blood. And, further, if a 0·5 per 1,000 solution of calcium chloride be added drop by drop to 1 c.c. of hæmothorax fluid, its original volume may be doubled without producing coagulation.

If therefore recent uncoagulated and incoagulable hæmothorax fluid is lacking neither in the thrombokinase, nor the pro-thrombin, nor the calcium salts, required for the formation of a clot, we must perhaps assume that it contains a substance which prevents coagulation.

If 1 c.c. of normal blood be added to 1 c.c. of hæmothorax fluid, that blood will lose its coagulability.

We carried out this experiment with the hæmothorax fluid from a dog, and with fluid from a hæmothorax of four days' standing in a patient, adding dog's and human blood respectively. In both cases the liquid remained incoagulable. There are limits, however, to this anti-coagulative action, for if we double the quantity of blood (for example one volume of hæmothorax fluid to two volumes of blood) coagulation takes place.[1]

We repeated this experiment, using the particularly coagulable fluid from a Morel-Lavallée effusion. A mixture of equal quantities remained incoagulable, although the Morel-Lavallée fluid coagulated rapidly in a control tube in which it had been collected.

We see no necessity for discussing the effect of diluting blood with other fluids. It is a known fact that a mixture of equal volumes of blood and serum

[1] While this volume is in the press we have repeated these experiments at the suggestion of our friend Ameuille, and we must admit that this inhibitory action is not constant, and that in the case of quite recent effusions it is absent.

coagulates in the same time and under the same conditions as pure blood.

Hence the fluid in a recent hæmothorax which has not coagulated in the pleura is also incoagulable outside it; it is also an anti-coagulative, since we have seen that it prevents the coagulation of normal blood and of sero-fibrinous fluids.

II. **The Fluid in a Hæmothorax is Hæmolysed and contains Bile Pigments.** — A second very interesting phenomenon which is usual in the early stages of the evolution of a hæmothorax is liberation of the hæmoglobin from the red corpuscles contained in the effusion. This hæmoglobin, which is readily recognised, colours the clear fluid or serum above the precipitated red corpuscles to a variable extent.

The fact that hæmolysis has occurred may readily be shown by aspirating 10 or 20 c.c. The fluid is left in a test-tube for several hours, or better still, if possible, centrifuged. The supernatant fluid remains a light- or even deep-red colour, and gives the characteristic spectrum of hæmoglobin.

Nature of the Hæmolysis. — The process usually begins soon after the formation of a hæmothorax, and seems to coincide with the development of incoagulability. In every case under our observation, whenever the fluid withdrawn by the first aspiration—which was carried out as soon as the condition of the patient permitted—proved incoagulable, it also exhibited more or less marked hæmolysis.

This hæmolysis is not immediate and rapid. At first it is only partial, and increases gradually to a maximum which is reached after a period varying with each case, usually between four and five, sometimes even ten days after the formation of the hæmothorax.

The fluid remaining after natural deposition or centrifugalisation is of a reddish tint, which later becomes a more marked or cherry-red, and sometimes so deep a red that it is impossible, without powerful

illumination, to distinguish the supernatant fluid from the precipitate of red corpuscles.

Hæmolysis is not so marked as this in every case. Any degree of coloration may be observed, and should be noted as a sign of some importance, which may be of value later.

In some cases hæmolysis cannot be detected, either because it has been extremely slight, or because a pleural effusion has occurred very early.

Duration of the Hæmolysis.—Whether hæmolysis has

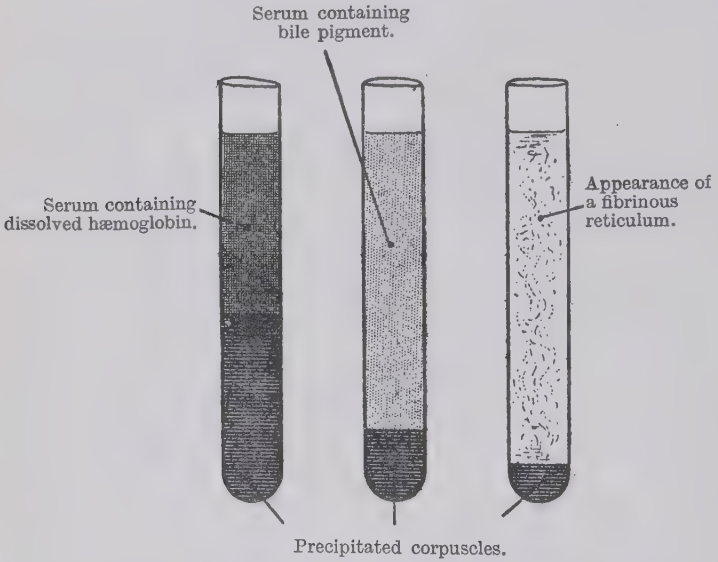


FIG. 13.—The first tube shows the fluid from a hæmothorax on the 1st day; hæmolysis is well marked. The fluid in the second tube was withdrawn about the 10th day. The fluid in the third tube was withdrawn on the 15th day.

been slight or pronounced, the colour produced by the liberation of hæmoglobin tends to disappear very quickly. Its average duration is ten to fifteen, and the maximum twenty days.

In 10 cases, however, of 70 which we were able to follow throughout their course, dissolved hæmoglobin

was present for over a month. It was present for a longer period in two of our cases, who had to be kept in hospital for nearly three months owing to recurrent intra-pleural hæmorrhage.

In the latter the quantity of dissolved hæmoglobin was considerable during the first fortnight, after which it diminished gradually, and finally remained practically constant, so that the centrifuged fluid was tinged a faint bright red.

Bile Pigments. — After the hæmoglobin has disappeared, the fluid becomes a yellowish or greenish-yellow colour, which shows up better when no longer masked by the presence of hæmoglobin.

Bile pigments are in fact present in hæmothorax fluid from the outset, and simply become visible as the hæmoglobin with which they are associated disappears.

The presence of *hæmoglobin and bile pigments* is further evidence of the peculiar changes which take place in a hæmothorax.

Bile pigments are not usually seen so early as hæmolysis. Dupérié found them as early as the second day, but this is exceptional. At first, when the fluid is deeply coloured by hæmoglobin, the bile pigments add a greenish-yellow shade which as the hæmoglobin gradually disappears is retained by the hæmothorax fluid.

The best method of demonstrating bile pigments in a hæmothorax is to apply Gmelin's test to the fluid after centrifuging or simply allowing it to stand, just as in testing for bile pigments in blood after the method of Gilbert, Herscher, and Posternak.

About $\frac{1}{4}$ of a cubic centimetre of fuming nitric acid is placed in a test-tube, which should be 1 cm. in diameter. Half a cubic centimetre of the fluid to be tested should then be added slowly by means of a pipette, care being taken not to disturb or mix the two liquids. After a variable interval, the bluish-green ring characteristic of the presence of bile appears at the junction of the two layers.

The pigment present is *bilirubin*.

Urobilin is also found, but not constantly (Guillain and Troisier, Dupérié).

Mode of Production of Hæmolysis.—*Corpuscular Resistance.*—When the red cells in hæmothorax fluid are examined at an early stage, or even some time afterwards, it is at once observed that their size and staining properties are normal and that no granular cells are present. Our observations agree on all points with those of Dupérié.

But if we investigate the resistance of these cells to hæmolysing agents, we find at once that it is diminished. Guillain and Troisier clearly demonstrated this some years ago. More recently Dupérié has published some interesting work on the subject, in which he goes so far as to base the prognosis partially on the results of this estimation of corpuscular resistance.

Normal blood to which saline solutions of decreasing strength are added is gradually hæmolysed by solutions containing 0·55 per cent. NaCl, hæmolysis being complete when the percentage is reduced to 0·35 per cent.

Now hæmolysis in hæmothorax fluid may commence in solutions containing as much as 0·80 to 0·90 per cent. *The resistance of the red corpuscles must therefore be greatly diminished.* An extremely interesting fact, however, is that *it is inconstant.* In certain cases the red corpuscles are hæmolysed in 0·75, 0·70, or 0·60 per cent. solutions, but hæmolysis is never complete and great numbers of red cells remain whose resistance appears normal or even increased (Dupérié) ; the latter phenomenon does not appear until a comparatively late stage in the evolution of the hæmothorax. This enables us to explain the partial hæmolysis of the fluid, which could not occur if all the hæmoglobin present were liberated at once.

Formation of Bile Pigments.—Hæmoglobin liberated in this way undergoes certain changes which ultimately result in the formation of bile pigments. It has been

proved chemically and experimentally that bilirubin is a pigment derived from hæmoglobin, and also that urobilin is similarly derived, representing a further step in the process.[1]

These pigmentary changes may be recognised in old hæmorrhagic foci, effusions, ecchymoses, etc. Froin clearly demonstrated the presence of bilirubin and urobilin in meningeal hæmorrhages and traumatic hæmothorax. Hence Guillain and Troisier's description of the change as "a kind of local hæmolytic jaundice," a phrase indicating that the formation of bile pigment is merely local.

What is the cause of this hæmolysis and the further changes which follow it? If blood from one animal be injected into another of the same species, a number of hæmolytic substances are produced in the organism which are capable of attacking the red corpuscles either of the same animal, when they are known as *autolysins*, or of another animal of the same species, in which case they are known as *isolysins*. The same phenomena are observed when hæmorrhage takes place into a serous cavity and the blood remains there. These lysins or hæmolytic agents, whose purpose appears to be to assist in the absorption of this hæmorrhagic fluid which constitutes an actual foreign body—these lysins may be present, either in the serous cavity into which hæmorrhage has occurred, or in the circulation.

If present in the blood effusion, they may be free, but more often they are located *in* the red cells. These cells are therefore sensitised and fragile, or in other words, readily hæmolysed (Guillain and Troisier). These lysins may readily be demonstrated.

Cytology of an Aseptic Hæmothorax in the Early Stages where no Exudative Reaction has occurred

An examination of the leucocytic elements in a hæmothorax is extremely interesting.

[1] Troisier's monograph is a complete and extremely interesting study of these phenomena.

Early observers studied the leucocytic reaction chiefly from the point of view of the reabsorption of the blood, and Froin's conclusions in this connection are most instructive.

The presence of large numbers of endothelial cells had already been noted, and the phagocytic function of these cells was demonstrated and described by Sabrazès and Muratet.

The next step was the discovery of a well-marked eosinophilia whose function was not determined.

These discoveries were followed by others of great importance, which not only solved the problem of blood-absorption, but also explained the evolution of a hæmothorax, with the result that we can now foresee the complications of this condition so accurately that the cytology of hæmothorax is now utilised in the form of cyto-prognosis, the principles of which have been laid down by Policard and Phelip. We shall confine ourselves, however, to the actual cytological study of the earlier stages in the evolution of a hæmothorax.

Quantitative Investigation.—The number of leucocytes is always greater at first than in the circulating blood. The count varies considerably and may be comparatively high.

In case No. 1 in Dupérié's monograph there were 32,000 whites to 4,681,000 reds on the second day in a simple hæmothorax.

This leucocytosis in an aseptic hæmothorax is exceptional; usually there are not more than 10,000 to 15,000 white cells to the cubic millimetre.

Rather later, on the seventh or eighth day, there is often a diminution which is only temporary, for the leucocytes again increase when an exudative pleural reaction occurs.

Qualitative Investigation.—*Polynuclear Cells.*—From the outset the percentage of polynuclear cells is above the normal. This phenomenon is absolutely constant. Dupérié found the proportion of polynuclears in

aseptic cases to be 90 per cent.; in a case of our own there were 88 per cent. of polynuclears on the second day. The increase in the number of polynuclear cells often proceeds more slowly and does not attain its maximum until the fourth or sixth day. The number is usually in the neighbourhood of 80 per cent.

These, which are neutrophile polynuclear cells, rapidly undergo a peculiar change in appearance, the nucleus becoming *pyknotic* [1] (Dupérié). This degeneration may first be observed on the second, fourth, or fifth day; it is well marked on the sixth and seventh days, but subsequently diminishes and disappears. This coincides with a general decrease in the number of leucocytes present. The number of polynuclear cells decreases particularly rapidly, and often falls to 15 or 20 per cent. of the total leucocytes present.

Mononuclear Cells.—Endothelial Cells.—Phagocytic Reaction.—While the number of polymorphs is decreasing, the number of mononuclear cells is seen to be increasing steadily. These cells vary considerably in shape and appearance.

Some resemble the ordinary mononuclear, and are not usually very numerous; others show a definite reniform nucleus, surrounded by non-granular protoplasm which stains very lightly.

Another variety is the large round cell, which is sometimes seen isolated in a field of red corpuscles, but more frequently in groups in which the cells are in contact, forming a sort of pavement.

The nuclei stain deeply with basic dyes, but the chromatin network is clearly visible.

The protoplasm contains no granules, and appears to consist of a network which stains rose-violet with hæmatoxylin and eosin. These are desquamated endothelial cells from the surface of the pleura.

[1] From Gr. *puknos*, thick, dense.—TRANSLATOR.

They may be present in large numbers, even amounting to 90 per cent. of the total (Froin and Chastenet de Giry).

These cells shortly exhibit vacuolation and amœboid movement, and slow staining with eosin shows the presence of remains of polynuclear cells, cellular debris, and red blood-cells in their vacuoles. Some of these red cells appear normal, but the majority are small and crenated, or even reduced to the form of large red agglomerations which are simply masses of degenerated red corpuscles, about to undergo absorption. In cases a little farther advanced, free iron pigments may be demonstrated (Leuret and Gauvenet).

This phagocytic reaction continues for some time.

The time of its appearance varies. In a few of our cases of hæmothorax in which the effusion was slight and absorption rapid, the reaction was evident on the second or third day.

More commonly it appears later—on the eighth or tenth day, and develops steadily until the stage at which the neutrophile polynuclear cells begin to disappear. We shall see that it is particularly well marked when the phenomena of absorption begin to be definitely established.

The more or less marked hæmolysis which occurs has no effect on it whatever, apparently neither intensifying nor inhibiting it. The average number of giant cells is rarely more than 40 to 45 per cent. of the total leucocytes, the other mononuclear cells amounting to 10 or 15 per cent.

Aspiration has a marked effect on this phagocytic reaction. It is commonly followed by the appearance of a liquid fibrinous exudate, with which the blood is diluted; the number of red cells decreases, and at this stage they seem to be absorbed chiefly through the lymphatics. Phagocytosis diminishes from this stage onwards. If, however, aspiration is not performed, and absorption is allowed to be carried out by natural

processes, the number of phagocytic cells decreases much more slowly.

Eosinophiles.—A very characteristic feature of hæmothorax is the frequent presence of eosinophile polynuclear cells in very large numbers.

These cells are ordinary eosinophiles identical in appearance with those present in normal blood, the nucleus being divided into two or three lobes which stain deeply, and the protoplasm full of coarse granules

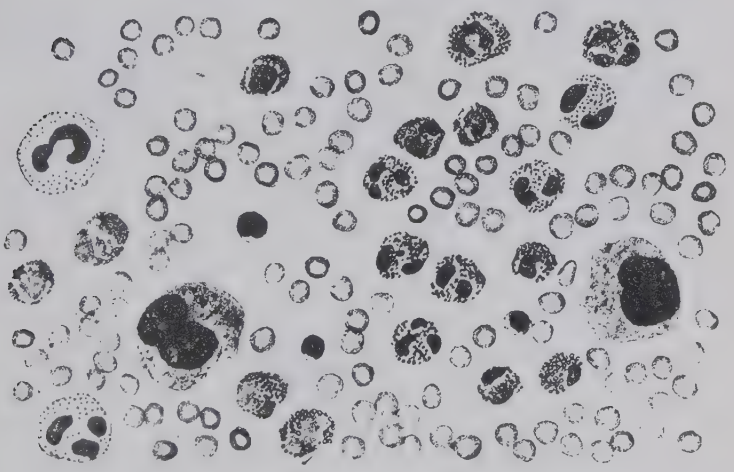


FIG. 14.—Cellular elements of hæmothorax fluid on the 8th day. The red corpuscles appear normal; eosinophiles are very numerous, a few neutrophile polynuclears are seen, also two large endothelial cells, one of which has a double nucleus.

which are stained readily by eosin, giving the cell a muriform appearance.

Mononuclear eosinophiles are also seen occasionally, but only in very small numbers.

These cells can be demonstrated particularly well by fixation in alcohol and staining with hæmatoxylin and eosin.

M. Fabre [1] recently suggested a method of selective staining which may be used with considerable advantage.

These cells appear in a hæmothorax at an early stage, usually at the same time as the giant cells, between the

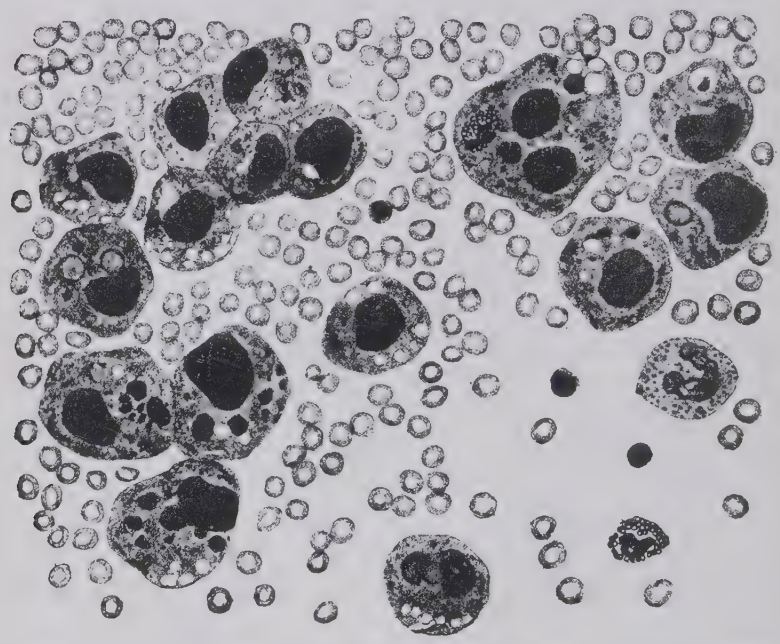


FIG. 15.—Macrophagic reaction on the 15th day of a hæmothorax. Many of these cells contain red corpuscles, cellular debris, and sometimes even eosinophiles.

sixth and the tenth day, sometimes earlier, but rarely later.

They may constitute 50, 60, or 70 per cent. of the leucocytes present. We shall also see that these cells

[1] FABRE, *Soc. Biologie*, January 6th, 1917, No. 1. The film is fixed with pure acetic acid (Zenker) or formalin (Dominici), stained deeply with hæmatoxylin, and then immersed in watery eosin (1 : 250) or alcoholic eosin (1 : 200). When the film is stained a uniform red, it is washed in a 2 per cent. solution of bicarbonate of soda for about ten minutes, then washed again in distilled water, and mounted. When decoloration has been carried sufficiently far, the protoplasm is decolorised completely, and only the granules and nuclei are stained.

remain in the effusion for a long period, and are often present during the secondary reaction of the pleura in the later stages of the condition.

The cause of this eosinophilia is still obscure and much debated. The proliferation of eosinophiles is especially provoked by bacterial toxins, and occurs around necrotic tissue and old hæmatomata (Bonnin). Fluids in which eosinophiles are present in large numbers are always full of toxins. It is a well-known fact that effusion from cases of sero-fibrinous pleurisy which contains eosinophiles is extremely toxic to guinea-pigs.

Are these eosinophiles produced in order to deal with toxins formed during the process of hæmolysis ?

However this may be, hæmothorax fluids containing eosinophiles are toxic. A guinea-pig weighing 600 grammes, inoculated with 30 cubic centimetres of hæmothorax fluid, in which there were 77 per cent. of eosinophiles, died in five hours, whereas double this quantity from a hæmothorax in which there were only 3 per cent. of eosinophiles had no effect on a second guinea-pig of equal weight. We know that fluid from a case of tuberculous pleurisy will kill a guinea-pig in a dose equivalent to 10 per cent. of the animal's weight (Péron).

Where are these eosinophiles produced ? This is a question with which we cannot deal fully at present. Two principal theories have been advanced. In the first place, it has been suggested that they are myeloid in origin, being produced in the bone marrow, where they normally originate (Weinberg and Seguin). They do not remain in the blood, but are attracted to the pleura. The number of eosinophiles in the circulation does, in fact, remain normal.

The alternative theory is that they are formed actually in the pleura, from the young cells in the perithelium of the vessels of the sub-pleural tissue. A local reaction will stimulate their formation, a process

which we may regard as a further example of the complex reactions which are produced in a hæmothorax.

A third, and scarcely tenable, theory is that eosinophiles are formed from degenerated red corpuscles, the latter being reduced to granules, and absorbed by neutrophile leucocytes.

Lymphocytes.—These are not numerous in the early stages of a hæmothorax; rarely more than 15 to 20 per cent. are present.

They are similar in every way to the ordinary lymphocyte present in the blood, consisting of a small deeply staining nucleus, surrounded by a lighter zone of protoplasm.

In a word, the cytology of the early stage of an aseptic hæmothorax is characterised in the first place by a neutrophile polynuclear leucocytosis, which is often marked, but only of brief duration, secondly by the appearance of giant cells, whose function is to absorb the red blood-cells, and lastly by the appearance of a considerable eosinophilia.

All these different cells are present in varying proportions in the successive stages of the evolution of the hæmothorax. We shall discuss the value of a cytological investigation in connection with the different clinical forms of hæmothorax.

EVOLUTION OF THE HÆMOTHORAX

Absorption of the Effusion.—The evolution of a hæmothorax, when it is not complicated by infection, normally tends towards absorption of the intrapleural effusion.

The rate of absorption is very variable; it is controlled by several factors, and its mechanism forms a most interesting study. Nevertheless, although the course of the condition is simple in many cases, in others, which form a majority, the pleura reacts sooner or later to the foreign body retained in it. A third, and exceptional, type of case is that in which the fluid

shows no signs of absorption, and may even appear to increase.

Let us examine these various conditions.

Simple Hæmothorax.—In about 10 per cent. of cases the hæmothorax fluid is absorbed fairly rapidly, and no secondary pleural reaction occurs.

The fluid is incoagulable from the outset, and remains so throughout the evolution of the condition. The resistance of the red cells, especially at the outset, is always much diminished, but varies with different cells. Hæmolysis is progressive and becomes more and more marked during the early stages.

The number of red corpuscles, which is approximately normal at first, sometimes remains the same for several days, and then decreases steadily

This decrease in the number of red cells may readily be estimated, provided, as Sacquépée suggested, the needle is always introduced at the same level, as the red corpuscles have a tendency to collect at the bottom of the pleural cavity.

The rate at which blood absorption is proceeding can easily be estimated by means of a hæmatinometer ; the method is as follows :—A needle is introduced (always at the same level), and 10 c.c. of fluid withdrawn into a test-tube (which is easily calibrated by lines cut with a file) and allowed to stand. After an interval of twelve to twenty-four hours, the relative proportions of serum and precipitated red cells are read off. This rough method of estimation is of the greatest clinical value, and affords an indication of the rate at which absorption is proceeding, with a minimum of trouble. For example, a case in which this test gave equal volumes of serum and red corpuscles on the second or third day showed subsequently a gradual and finally a sudden decrease in the quantity of red cells, the proportions then being a volume or half a volume of precipitated red cells to nine volumes of serum.

Hæmolysis is not the only cause of this decrease in the

number of red cells. They are also absorbed by the giant cells (see Fig. 15) and carried away by the lymphatics.

Numbers of these large endothelial cells are present, and ingest quantities of red blood-cells. Some of the latter appear normal, but many have already undergone a series of changes.

This stage of absorption by phagocytosis often, but not always, coincides with a more or less well-marked eosinophilia. Ultimately the fluid gradually disappears, the white cell which appears to predominate in this terminal stage being the lymphocyte.

Hæmothorax and Pleurisy with Exudation.—This is a common complication, developing as a rule some time after the formation of the hæmothorax. It is an invariable accompaniment of a large effusion.

The first stage in such a case presents the same features as have been described already as typical of simple hæmothorax; the cell reactions are the same, the fluid is incoagulable, and hæmolysis occurs. Later, however, towards the tenth or fifteenth day, sometimes earlier, and rarely later (although we have seen several such cases), and *often soon after aspiration has been performed*, the fluid which is subsequently withdrawn and allowed to stand is found to separate into two layers. The precipitate of red corpuscles is much smaller than before, and the supernatant serum much clearer, and coloured a greenish yellow. The distinctive feature, however, is a *fibrinous reticulum* which forms above the layer of red corpuscles, without involving them, and rises like a thin veil or mass of light gauze floating in the serum. In subsequent specimens of the fluid it may be more marked, but coagulation *en masse* never occurs (see Fig. 13).

The chemical composition of this fluid is as follows (specimen obtained on the tenth day):

Specific gravity .	1·026.
Albumen . .	10 grammes per litre.

Fibrin	2·31.
Solids	74.
Urea	0·16.
Phosphates	0·34.
Chlorides	4·56.
Bile pigments	traces.
Urobilin	nil.
Cholesterin	Actual quantity not estimated.

The cytology of this stage of fibrinous reaction is characterised by a decrease in the number of neutrophile polynuclears, and an increase in the number of eosinophiles, which varies from 20 and 30 to even 50 per cent. of the total leucocytes. Giant cells are still present in considerable numbers (20 to 30 per cent.).

Hæmothorax and Sero-fibrinous Pleurisy. — In some cases, 9 per cent. according to Dupérié (in our series they amounted to 6 per cent.), the hæmothorax is, so to speak, superseded, after a short period, by sero-fibrinous pleurisy. When fluid is withdrawn, the entire contents of the test-tube coagulate, the fibrinous clot enveloping the red cells present, which are usually not very numerous, as partial absorption has already taken place. This condition is one of definite sero-fibrinous hæmorrhagic pleurisy; chemical analysis frequently indicates the presence of a large amount of fibrin and a quantity of urea which may amount to 7·5 grammes per litre.

The chief cytological feature of the condition is the presence of numerous lymphocytes, which may amount to 96 per cent. of the total cells (Case V, Dupérié); these have gradually replaced the eosinophiles and giant cells which predominated in the earlier stage of simple hæmothorax.

Hæmothorax with Persistent Hæmolysis.—Very occasionally (in only two of our cases), the fluid remained incoagulable for a surprisingly long period (two and a half months, and three months). This incoagulability

was accompanied by hæmolysis, which was also persistent, in the sense that the serum remained bright red. While the condition persisted, the red cells underwent changes which resulted in their almost complete destruction. The precipitate from the fluid aspirated contained only the colourless stroma of red blood-cells, shrunk into small rounded bodies, and crystals of hæmatoidin. The cytology of the condition is very interesting. During the first ten days, it reproduces the features of a simple hæmothorax; namely, the proliferation of neutrophile polymorphs at an early stage, and of giant cells shortly afterwards. Eosinophiles, however, are very few or absent. Mononuclear leucocytes appear subsequently, and eventually predominate.

Lastly, at about the fifth week, numbers of polymorphs make their appearance, and are present in considerable numbers, until the fluid, which remains sterile throughout, is completely absorbed.

CHAPTER II

SYMPTOMS OF WOUNDS OF THE PLEURA AND LUNG

The clinical symptoms of pleuro-pulmonary wounds are so extremely variable that each case may almost be said to represent a different type.

We may nevertheless usefully classify the commoner clinical features, and follow their development without rendering that classification too arbitrary or attributing to any individual symptom a significance which it does not possess.

A characteristic feature which is the first to arrest attention is a combination of functional symptoms, the intensity and duration of which appear to be directly proportional, up to a certain point, to the severity of the lesion. Associated, as they are, with a number of general phenomena, they serve as a basis for all the clinical descriptions of pleuro-pulmonary wounds which have been given since Sencert's classification in 1915.

The effects produced by the intensity of the general phenomena in chest wounds are not always immediately evident. The conditions of the battle, and the situation of the man when he is hit, must be taken into consideration. Some men will collapse at once, and remain prostrate in an asphyxiated condition, with livid features, for some minutes, after which they will recover and make perfectly satisfactory progress. Others on the contrary scarcely realise that they are hit, but soon afterwards exhibit the general phenomena

of asphyxia, respiratory difficulty and thoracic compression; these are the cases that may die in the communication trenches before reaching an aid post.

It is not until somewhat later that the symptoms become definite, and the severity of the patient's condition can be estimated.

In some cases, general symptoms are almost completely absent and functional disturbance is slight. There is nothing beyond the physical signs to indicate that the lung is involved. Such cases are described as of the "*mild type*."

On the other hand, the general signs may be well marked, functional disturbance—*i.e.* pallor, anxiety, agitation, intense dyspnœa, and a rapid pulse—being more definite than the physical signs; although the extent of the effusion, and hæmoptysis, may be only moderate. Such cases are of the "*intermediate type*."

Lastly, in the final class, are cases in which the general condition is extremely grave, and functional disturbance is intense, while the physical signs indicate a serious lesion. This is the "*severe type*."

Although all surgeons are in agreement as to the treatment of cases falling into the first and second categories, there has been considerable difference of opinion in connection with the third group.

1. **Mild Type.** — Characterised by the slightness of the effect on the general condition and by functional disturbance which is soon relieved, this type of case is notably the clinical corollary of penetrating wounds in which a bullet, in traversing the lung, does little or no damage. This very satisfactory type of case was common in the early part of the war, and is still by no means rare. The existence of such cases gave rise to a belief in the benignity of a large proportion of chest wounds; here again experience has shown that it is unwise to generalise too hurriedly. This type, forming about 30 per cent. of the cases

which reach hospital, sometimes includes cases which have been wounded by small shell fragments.

A man is struck by a bullet at short range. Sometimes he only experiences a pricking or burning sensation, and is only aware that he is wounded when he notices that his clothes are wet with blood. On the other hand, the impact is often more violent. The usual sensation is rather that of a sudden blow which surprises and stuns than of a sharp tearing and radiating pain. The man is brought to a standstill, and often falls, but rarely loses consciousness. He will usually move away shortly afterwards. In the early days of the war, cavalrymen were known to have kept the saddle for hours after being shot through the chest. As a rule, if the wound is received during an attack, the man instinctively moves to a place of safety.

This initial effort which the man makes is often prolonged, and sometimes is accomplished with comparative ease, but before very long two symptoms supervene: *dyspnœa*, which is constant, and *hæmoptysis*, which may sometimes be absent.

Dyspnœa may develop immediately, in the form of an attack of asphyxia—a sort of spasm of suffocation a few moments after the infliction of the wound. This is a rare occurrence, and in any case is only momentary, as the man is obliged to lie still, and relief follows rapidly.

More commonly, dyspnœa is progressive, and is notably increased by the effort involved in walking. It is slight at first, and gradually increases, until it amounts to severe distress. If the man stops to rest, it is relieved. Many of these cases arrive at the aid post supported by others, or leaning on their rifles. The greatcoat is open, the cartridge belt, gas mask, and anything else which may interfere with their breathing have been thrown aside (this is one of the first things they do). All they want is to be able to rest, and to

get their breath for a fresh attempt at reaching an ambulance car.

An important feature of the dyspnœa in these slight cases is that it is relieved very quickly by rest, and reappears almost immediately on exertion.

Maisonnet gives some striking illustrations of the importance of rest; one of his colleagues immobilised all chest cases at the aid post of which he was in charge, and immediately applied the usual medical treatment. These cases arrived at the ambulance so perfectly comfortable, and with so little dyspnœa, that they could readily be recognised as having been sent down from that particular aid post.

The exigencies of war surgery do not, however, accommodate themselves to such simple rules as these.

Hæmoptysis is not present in more than 50 per cent. of these cases. A few moments after the shock of the injury, the man in coughing may spit up some bright blood, which is often frothy; in other cases, hæmoptysis only develops after exertion. It is rarely profuse. Here again everything depends in the great majority of cases on the amount of exertion which has been necessary.

In addition to these initial symptoms which characterise the onset, there are two others, which are less frequent.

Cough sometimes accompanies the hæmoptysis.

Pain, which is occasionally very severe at first, but diminishes, only persisting in a marked degree when there is injury to the ribs.

When the patient has been evacuated from the aid post to the ambulance, the general appearance and functional disturbance depend rather on the amount of effort which the man has been obliged to make than on the injury itself.

With some degree of dyspnœa, and still coughing up mucus streaked with blood, the patient's general appearance is hardly suggestive of a serious case. He

will often be sitting up on arrival, and seem comparatively unaffected by the jolting he has received on the way. Examination, after removal of the clothes, in the great majority of cases reveals the fact that the wounds of entry and exit are punctiform and completely closed ; sometimes there may be a small area of subcutaneous emphysema surrounding one of them. In others there may be a more or less extensive hæmatoma.

Superficial examination reveals a definite sign, which is almost constant, viz. *immobility of the affected side*, particularly in its lower part. The superficial muscles of the thorax and the intercostals remain quiet in a state of contraction. If the two sides of the chest are compared, it is clearly seen that movement of the ribs is either very slight or entirely absent on the affected side. It seems as though the muscles contract permanently in order to immobilise the deep parts of the wound as far as possible, and to limit respiratory efforts, which might dislodge a clot, or aggravate an incipient pneumothorax. This muscular rigidity also involves the diaphragm, its range of movement being considerably reduced, a phenomenon which can be observed under X rays.

The percussion note is approximately normal, although its resonance may perhaps be slightly diminished.

Diminished breath sounds, and sometimes coarse râles, are heard on auscultation.

It is exceptional to find evidence of fluid effusion ; more commonly, signs of pneumothorax are present, although only slightly marked, the chief being definite hyper-resonance at the apex.

The temperature is usually normal on arrival, but some cases show a slight degree of fever, never exceeding 102° on the first day. The pulse is always somewhat rapid, but never more than 100.

The patient may remain in some distress during his

first few hours in hospital, but warmth and comfort bring rest and sleep. On the following day his condition is greatly improved, respiration is easier, pain is absent, and even if hæmoptysis has been present on the evening of his arrival, bright blood is very rarely brought up during the few days that follow. As a rule, these patients only expectorate a small quantity of dark, and subsequently black, blood, which disappears entirely in three or four days. The absorptive changes in the focus of pulmonary hæmorrhage, which is usually quite a small area, can be followed by auscultation. This area is only recognisable by the moist râles which are caused by the passage through the bronchi of some of the blood which has escaped into the alveoli. From this stage onwards, these cases rapidly recover. In a few days their appearance is normal, and their appetite good; the temperature rapidly returns to normal, and the general condition is excellent.

The wound heals in a few days, and a radiogram shows no injury to the lung, which is functioning perfectly within eight or ten days. By that time the physical signs and dyspnœa have disappeared and the patient is convalescent. These cases may be evacuated in a fortnight, which is ample time to ensure their complete recovery.

Intermediate Type. — In the initial stage this type resembles the foregoing in all respects, but functional disturbance soon becomes more marked, aggravated, as it often is, by exertion, prolonged and painful effort, cold, rain, and exposure. Many of these men, if they could rest quietly on the way back, would be in a much less serious condition than is usual on their arrival at the ambulance. The greater number, in fact, tell us that their difficulties began when they were obliged to walk a long distance at night; staggering along, halting frequently, in great pain,

and finding it almost impossible to breathe, many of them fall unconscious, and a final effort provokes serious hæmoptysis. Subsequently the man, pale, anxious, and fatigued, is carried to an ambulance. Dyspnœa is intense, and all the accessory muscles of respiration are brought into play. The breathing is shallow and the voice husky; the patient moans feebly and complains of severe thirst, but as far as possible avoids speaking, because every effort increases the dyspnœa and provokes coughing which is always intensely painful. The expression indicates agitation and anxiety, the result of air hunger; the least movement is torture, and he asks in a feeble, halting voice that he may not be moved. On entering a ward for chest cases, one is struck by the silence of the place. A man who is wounded in the chest remains still and silent long after his arrival. In other wards, on the other hand, the men are restless, talking, complaining noisily, all interested in what is going on around them; the "chest cases," lying down or half sitting up, neither move nor speak, absorbed as they are by a single need, the need of air.

The functional phenomena are always marked at first, but after a few hours of rest they subside to a great extent; and as medical treatment is begun immediately, its effects must be taken into account in considering the symptoms. An injection of morphia rapidly reduces the extreme initial dyspnœa, although it will, of course, reappear if any exertion is attempted.

Hæmoptysis, which is sometimes profuse, may continue for several days. As in the foregoing type, dark clots appear instead of bright blood—usually on the third or fourth day. Hæmorrhage has now ceased, but the blood in the alveoli is being coughed out. This distinction is of great importance; so long as the blood expectorated is bright red, the patient's condition justifies anxiety, since the lung is evidently still

bleeding. The prognosis improves when the sputum becomes darker.

Pain is of some importance, and must be taken into consideration. If it persists and is increased by deep inspiration, or by moving or coughing, fracture of a rib or pneumothorax should at once be suspected.

The temperature is always raised. A few cases arrive with a subnormal temperature, but it rapidly rises to 102°, and often higher, on the second or third day.

The pulse is always rapid, sometimes 120 or 130, sometimes uncountable, and of low tension; we have always obtained low readings with a sphygmo-manometer in cases where hæmorrhage and shock were marked. A remarkable improvement in the pulse, however, is produced by rest.

Severe Type. — Cases of this type are much less common, at least if we understand by "severe" cases only those of this type which succeed in reaching an ambulance.

As Hartmann aptly observes: "severely wounded chest-cases cannot travel." Many are unfortunately killed outright. According to Duponchel's statistics, a third of these cases die at the aid post before they can be evacuated; such as arrive at the divisional ambulance—a small minority—have survived the strain and danger of evacuation. It should clearly be understood that we are considering cases wounded in the chest only, because many of the patients who are severely shocked have multiple injuries, and the chest wounds are only partially responsible for their condition.

Cases of the severe type exhibit well-marked shock: a striking and obvious feature is the livid pallor of the face and the collapsed appearance of the whole body, only the muscles of respiration seeming capable of action.

Some lie flat, others are half-sitting up, and all are in a condition of extreme weakness. The dropping of the lower lip and jaw, and the position of the head, which falls forward on to the chest or on the shoulder, are suggestive of anxiety and suffering. The lower limbs are extended and the arms lie alongside the body, in complete relaxation. Every ounce of possible effort is reserved for the muscles of respiration. The sterno-mastoids, pectorals, and the intercostals exert all their power to draw in air, with a regular and rapid movement, corresponding with dilatation of the nostrils. In a word, dyspnœa is intense and respiratory distress, that terrible sensation of death by suffocation, is perhaps even more in evidence. The least movement brings on suffocation ; hence it is by gesture that the patient tries to make himself understood and to call attention to his distress. He will often subside into a quiet delirium, and mutter disconnectedly and unintelligibly, only coming to his senses when spoken to, or when coughing.

The pulse is extremely rapid, 120 or 140, and so weak as to amount to no more than a flicker, which is sometimes scarcely perceptible. Cardiac weakness may cause faintness or actual syncope, which often causes sudden death in these cases.

In some cases the wound appears small and insignificant, and only a small stream of blood trickles from it. Often the wound does not even bleed at all.

But side by side with these cases of severe type with a *closed thorax*, we must consider those in which the *thorax is open*.

In the latter, a new phenomenon attracts the surgeon's attention, *traumatopnœa*. The patient is generally covered with blood, for the wound bleeds freely, and, as we shall see later, there is nothing in these cases to limit the hæmorrhage.

If the wound is a large one, the air passes in and out at each respiratory movement with blood, which is

shot out forcibly with a noisy gurgling like that of a badly adjusted pump.

If the orifice is small, and especially if it is on the front of the chest, the current of air produces a faint regular whistling sound, which may change in quality or cease altogether if the skin in the neighbourhood of the wound is displaced with the finger.

PHYSICAL SIGNS

Examination of a Patient with a Chest Wound

There are certain fixed principles to be observed in this examination, departure from which involves serious and even fatal risks.

The patient should be immobilised immediately on arrival, however slight the injury may appear to be. He should immediately be placed in bed, and there made warm and his wound dressed. Waiting and examination in the dressing or admission rooms, immediate X-ray examination, and passage along draughty corridors, or from hut to hut, etc., must be absolutely avoided.

It should be an absolute rule that the patient be taken without delay to the particular ward in which he is to remain. He should be propped up in bed, and only be examined if serious signs, such as those of persistent hæmorrhage, or asphyxiating pneumothorax, suggest the necessity of an immediate operation.

An examination of the front of the chest, which can be carried out without moving the patient, is sufficient in the early stages to give a fairly clear idea of the presence of a pneumothorax or hæmothorax. The apex beat is located, and by light percussion a comparative examination made of the two sides of the chest. An exploratory puncture made in front, in the third intercostal space, a little outside the nipple line, will corroborate the evidence obtained by percussion.

The back should not be examined until the patient has recovered from the initial distress and shock.

The difficulty of the examination is considerable, and is largely due to the fact that the patient cannot tolerate the upright sitting position.

It is a remarkable but generally recognised fact that a man with a chest wound has great difficulty in sitting upright in bed ; for in this position the legs and thighs are flexed and press against the abdomen, further increasing the difficulty of respiration.

There is an easy way, however, of obviating these difficulties. The patient is turned in his bed, half-

Fig. 16.

sitting up, so that eventually his legs are hanging over the edge of the bed ; from this position he can be raised, without any effort on his own part, to a sitting position, and by resting his hands on the bed or on his knees he will be able to undergo the examination with little fatigue (see Figs. 16–18).

The effects of a pleural or pulmonary lesion are by no means invariably indicated by clear and well-defined clinical signs. The value of such signs as there are requires careful consideration, and the difficulty of interpreting them is sometimes considerable. But

whatever the clinical type of the case may appear to be on admission, there may be either air or blood in the pleural cavity, or there may be evidence of a pulmonary lesion. How can these various conditions be recognised ?

Signs of Pneumothorax.—We know that pneumothorax is rarely simple, and in these cases it is more often localised than general. Usually air and blood are

Fig. 17.

present together in the pleural cavity, and signs of both can be detected. It is common for the signs of pneumothorax, which at first are more marked, to disappear gradually, giving place to those of hæmothorax.

Simple complete pneumothorax is therefore uncommon ; the physical signs, when it occurs, are those which are typical of the condition. The affected side is immobilised, and almost rigid, and is sometimes also distinctly barrel-shaped.

The anterior wall of the chest is more resilient to percussion than usual, and the note is loud and tympanitic, but the greater the intra-thoracic pressure, the less these signs are marked, and with a high pressure the note may seem almost dull.

On auscultation, particularly in the region of the hilum, a characteristic amphoric hum is audible,

Fig. 18.

and the "bell sound" (the *bruit d'airain* of Trousseau), which is easily elicited, completes the picture.

Limited pneumothorax is much more common, but the physical signs of this condition are sometimes indefinite. They are usually to be detected at the apex, but may be localised lower down in the axilla. We have already referred to the important part played by adhesions in limiting a pneumothorax. The area involved is found to be more elastic and resonant to percussion, the respiratory murmur is diminished, sounding thin and distant, and an amphoric hum,

which is not always distinct, may sometimes be heard when the patient is made to cough. The bell sound, however, is more useful than anything else in defining the region affected.

Signs of Hæmothorax.—The physical signs are often ill defined at first, as they are frequently masked by signs of pneumothorax. The chief immediate necessity is to decide whether the serious functional phenomena which the case presents are due to the presence of air or of blood. It is not desirable until some days later to attempt any more precise conclusions as to the signs of intra-pleural hæmorrhage.

These signs are the signs of pleural effusion. They are never so definite, however, as those of sero-fibrinous pleurisy. There are two principal reasons for this: the nature of the effusion, and the fact that the lung as well as the pleura is often involved.

Here we repeat one essential principle. The patient should be examined by carefully comparing the two sides of the thorax.

Arching is often well marked, especially in the lower part.

Immobility is a particularly definite sign, and should at once attract the attention. It is usually limited to the base or the lower part of one side, while the upper part still moves, more or less irregularly, and if dyspnœa is marked, somewhat jerkily.

Vocal fremitus is of no value as a sign, since the patient cannot speak in a loud voice.

Percussion, on the contrary, is extremely important. The area of dullness in a hæmothorax is often clearly defined, being limited above along a definite line. Percussion alone is of course not sufficient to establish a diagnosis, but utilised on a definite plan—*i.e.* by percussing from above downwards and comparing the note with that of the opposite side—it constitutes evidence of the greatest value.

Auscultation.—In a third of these cases, the auscultatory picture is complete and is absolutely diagnostic of the existence of a fluid effusion. The signs are as follows: absence of the respiratory murmur over a more or less extensive area; high-pitched distant bronchial breathing, heard especially during expiration and clearer towards the upper part of the effusion in the region of the hilum; ægophony and pectoriloquy when whispering.

How often are these signs absent?

In a good half of the cases, auscultation only gives one sign, absence of the respiratory murmur over a more or less extensive area, which is often very difficult to interpret and may in many cases, particularly at the outset, be due simply to immobilisation of the thorax. In some cases the presence of subcutaneous emphysema interferes with accurate auscultation, as the sounds are masked by the loud crepitations which every movement produces in the subcutaneous tissues.

The coin test, systematically applied, gives more precise results in the great majority of cases than any other sign. It is daily of enormous value to us, and is so simply and easily applied that it seems surprising that it is not more in vogue. The technique is the same as that employed in eliciting the bell sound of Trousseau, and was originally used in cases of serous pleural effusion by Pitres.

The stethoscope is applied at a point directly opposite to that at which the coin is struck with the edge of a second coin. The sound produced in this way is distant, muffled and dull, *i.e. wooden*, when the chest is normal. But when the pleural cavity contains fluid, the sound is clear, and metallic, giving an impression of being produced in the immediate vicinity of the ear. The line of demarcation between the effusion and the normal lung above it is well defined. A blood effusion gives exactly the same signs, and by shifting the point

of percussion downwards the upper limit of the fluid can readily be defined.

Exploratory Puncture.—This procedure is of great value, but at the same time it must be carried out methodically. In the first place, sufficient care is not always taken in regard to the instruments to be employed. A syringe with a capacity of 10 cubic centimetres should be selected and, of course, sterilised. Pravaz's needle is too small to give satisfactory results. A needle $\frac{8}{10}$ millimetre in diameter, such as is used for intra-venous injection, should be employed; the most turbid effusion can be withdrawn with a needle of this size.

The needle should be introduced in the centre of the area of dulness (there is always a tendency to insert it a little too low). There is no point of election. The particular intercostal space selected will vary with the case, and the operation can be repeated as often as may be found necessary. When fluid is withdrawn, it should always be collected in a sterilised test-tube.

X-ray Examination.—It is not our purpose to

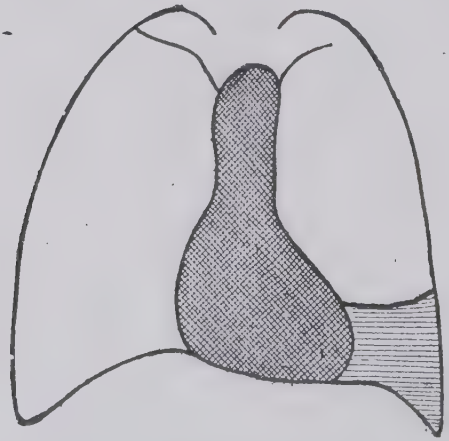


FIG. 19.—Radiographic diagram of a small hæmothorax.

enlarge on the technique of X-ray examination. As a means of verifying conclusions based on the physical

signs described in the foregoing pages, it constitutes an important element in diagnosis. We must, however, emphasise our opinion that such an examination as

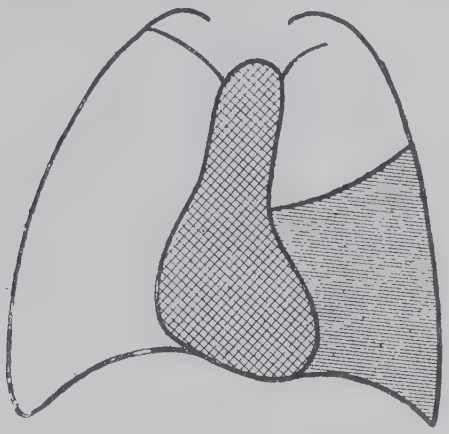


FIG. 20.—Radiographic diagram of a hæmothorax of moderate degree.

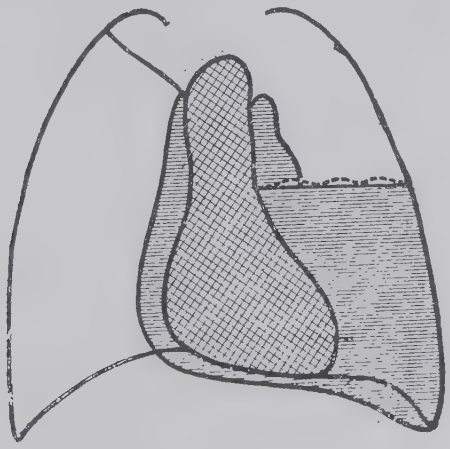


FIG. 21.—Radiographic diagram of pneumo-hæmothorax.

this, which is always trying and often even harmful to the patient, should be postponed for several days at least, except of course in exceptional cases.

The rules for the examination of any pleural effusion

apply equally to hæmothorax It would appear that in its early stages, owing to the greater density of the fluid, the line of its upper boundary is usually horizontal; it is clearly defined and shifting. This shifting is particularly evident when the effusion is assocated with pneumothorax.

The upper level of an effusion of moderate amount sometimes shows a certain obliquity, suggestive of Damoiseau's curve; experience shows that in these cases hæmothorax is complicated by exudative pleurisy. Variations in X-ray appearances will be described in connection with each type of case.

Pulmonary Symptoms.—We have already considered the immediate effects of rupture of the lung surface. These effects, such as the escape of air into the pleural cavity and intra-pleural hæmorrhage, are not the only results which may follow. What changes occur in the lung as a result of the injury to it, and to what clinical phenomena does that injury give rise ?

1. In some cases, even a wound of the lung will produce no effects whatever in the form either of physical signs or of functional disturbance. There is no hæmoptysis, no cough, and no abnormality on auscultation. Under X-rays both the lung shadow and respiratory action appear normal.

2. *Pulmonary Hæmatoma.*—Post-mortem examinations have shown us that intra-pulmonary hæmorrhage consists either of a simple infiltration of the alveoli around the track of the projectile, or a localised hæmatoma, or a diffuse and comparatively extensive hæmatoma, or hæmorrhage remote from the actual lesion. These lesions, which are purely mechanical, and are partially cleared up by hæmoptysis, can be detected by clinical examination, whether any inflammatory reaction has followed or not. Pulmonary hæmatoma, as we have frequently observed, possesses distinctive characters, which are due simply to the presence of blood in the lung tissue itself.

In the simplest cases, methodical auscultation of the lung on the affected side will lead to the discovery of a small area at the apex, or lower down, or sometimes in the axilla or anterior to it, where dry râles can be heard, with no bronchial breathing or other adventitious sound; the nature of these râles depends, of course, on the condition and amount of the blood which is in the alveoli or in process of expulsion though the bronchioles.

In other cases, a more diffuse hæmatoma is present. Its existence may be suspected, for instance, if it is near the apex, where it is not obscured by a pleural effusion. Percussion gives an impaired note, combined with a feeling of resistance and less resilience. Although signs of compensatory breathing might be expected, the breath sounds are found to be diminished in this area; sometimes there is bronchial breathing with increased vocal resonance and coughing evokes râles which frequently sound moist.

The presence and exact position of the hæmatoma can be verified by a radiogram. The latter will show a definite shadow, with somewhat vague and ragged margins, varying in depth with the size of the hæmatoma.

It is commoner for a pulmonary hæmatoma to be almost completely masked by a co-existent pleural effusion, and in such cases it is impossible to differentiate the signs due to the two conditions.

A number of rather puzzling observations, and the possibly unjustified assumption of similarity between the evolution of a pulmonary hæmatoma and that of a Laennec's infarct, have gradually led to the conclusion that some degree of inflammatory reaction always takes place in any focus of intra-pulmonary hæmorrhage. It is stated that this reaction may be merely congestive, but more commonly leads to actual hepatisation, or, as it is sometimes described, "the lighting up of pneumonia."

In Piery's words, "Simple penetrating wounds of the chest are uniformly characterised, as much on anatomical as on clinical grounds, by the constant appearance of *a hæmo-pleuro-pneumonic syndrome*—that is to say, by the simultaneous production of a pneumonia and a hæmothorax."

We have already referred to the discovery, post-mortem, of traumatic pneumonia (see p. 703). If this were as common as Piery suggests, we should have found instances of it in the numerous autopsies we have conducted. But, histologically, we have never seen true hepatisation on the injured side. We have already described the lesions which are commonly discovered and might by their appearance suggest pneumonia. Similarly, the fact that an area of lung seems hardened to the finger in the course of a surgical operation is not sufficient to establish a diagnosis of pneumonia.

On clinical evidence, we have come to the conclusion that Piery's arguments are not convincing, and are not sufficient grounds for assuming that pneumonia is constant in pleuro-pulmonary wounds. The signs which he gives are the following:—Posteriorly, absolute dullness at the base with complete absence of vocal fremitus and breath sounds; at a higher level, tubular bronchial breathing, sometimes a little less marked than in lobar pneumonia, and in some cases soft and remote, similar to that met with in a case of pleural effusion. This sound is sometimes, but not always, accompanied by râles, which may be either crepitant or sub-crepitant, or by friction sounds.

These signs are equally typical of a pulmonary hæmatoma, subjacent to a hæmothorax. Similarly Piery attaches great importance to the expectoration of dark blood which follows the bright-red hæmoptysis of the onset, and which, according to him, is characteristic of pneumonia around a hæmorrhagic focus. In all our cases the sputum has been practically black,

and characteristic of a pulmonary hæmatoma which is being eliminated.

Bacteriological observations seem equally valueless in supporting his theory; in observation No. 1 of Piery's work, where the inoculation of a mouse revealed the presence of virulent pneumococci, the case in question was that of a man who, in addition to the hæmo-pleuro-pneumonic syndrome on the right side (the side of the injury), had a pneumonia on the left side. This case suggests a different aspect of the subject. It is quite another matter to assert that pneumonia cannot co-exist with a chest wound. When it does appear, it is usually on the opposite, and not on the injured, side.

The study of numerous cases has led us to the same conclusions as Latarget, who insisted on the important part played by the effusion as an immobilising agent, not only in the spontaneous arrest of hæmorrhage from the lung, but also in preventing infection of the lung through the air passages, its action being to produce collapse and hence to prevent movement.

What conclusions are to be drawn from all this? Traumatic hæmatomata of the lung possess their own peculiar histological and clinical characters, which have too often been overlooked. Are we to conclude that inflammatory changes never occur in a hæmatoma? We do not pretend to make any such assertion; inflammatory reaction, which is exceptional in a lung compressed by a hæmothorax, is more likely to be met with when intra-pleural effusion is slight or absent. These complications will be considered in the same connection later (see p. 777).

EVOLUTION

The evolution of a pleuro-pulmonary wound does not necessarily coincide with the conclusions drawn as to its severity on the patient's admission to hospital.

One case, labelled slight and benign, may subsequently develop complications, and become serious. Another, regarded as serious and treated accordingly from the outset, will make rapid and satisfactory progress. Immediate aspiration may at once prevent complications which are threatening. A gaping thoracic wound, which is closed at once, may follow a benign course.

The varieties of evolution which we shall illustrate from the foregoing biological and clinical data are not amenable to arbitrary classification. Here, if ever, each case represents a fresh type; a few main distinctions, however, may serve as a guide to the surgeon in diagnosis and in after-treatment.

Types of Benign Evolution.—We have already mentioned that some of these cases recover rapidly, without any ill effect on either the pleura or the lung being apparent.

A few instances of this may be met with in practice; there is slight limitation of movement on the affected side, but no abnormal sounds are heard on auscultation, and the respiratory murmur, which is slightly diminished at first, rapidly becomes normal. Everything clears up as though the lung had not been injured at all. These cases, however, are somewhat rare, and do not represent more than 10 per cent. of "slightly wounded" chest cases.

In a few days the patient's general appearance is normal, and his appetite quickly returns. The temperature rarely exceeds 100°. X-ray examination shows that the lung movements are normal; the phrenico-costal sinus is clear, and the two sides are identical.

Briefly, functional signs disappear rapidly and physical signs are slight or absent.

The course is equally favourable, even in cases where a projectile is retained in the lung, but this must not be understood to imply that a foreign body

will never cause trouble, more particularly some time later.

A favourable result of this kind often follows when an open wound in the thorax has been closed by early operation.

Sometimes the presence of a pulmonary lesion, of which hæmoptysis furnishes objective evidence, can be recognised by auscultation. A small hæmorrhagic focus can be detected, which quickly disappears as the blood which has escaped around the track of the projectile becomes absorbed.

In native troops, who constantly suffer from bronchitis, the latter is often aggravated, but beyond this no ill effect follows.

In some cases, the pleura seems chiefly to be affected, and friction sounds heard at the base are apt to be very persistent.

Simple Pneumothorax, complete or localised.—Apart from valvular pneumothorax, which is a serious complication (see p. 769), the evolution of a pneumothorax is usually benign.

The air is absorbed rapidly, and in ten or fifteen days everything is normal; the fever of the first few days also disappears rapidly, and the general condition quickly improves.

Traumatic Effusion.—1. *The effusion develops and is absorbed without incident.*—Here we are usually dealing with a small hæmothorax. The physical signs are clear, and diagnosis is easy. Aspiration gives an incoagulable fluid which separates on standing, leaving serum coloured by hæmoglobin. The cytology of this effusion, which has already been described, is interesting, but results are not constant. We shall here resume what has already been said in this connection.

Macrophagic reaction is constantly met with, and is very soon in evidence, but eosinophilia may be absent.

The following are two examples:

Lieut. Pr. . . ., effusion estimated at 500 grammes, absorbed

in fifteen days, gave the following white count on the eighth day :

Neutrophile polymorphs	3·4 per cent.
Eosinophile polymorphs	44·8 ,, ,,
Lymphocytes	4·8 ,, ,,
Macrophages	47·0 ,, ,,

Lang . . ., small hæmothorax following a through-and-through wound of the right scapular region, absorbed in twelve days. Incoagulable hæmolysed blood gave the following count on the sixth day :

Neutrophile polymorphs	28 per cent.
Eosinophile polymorphs	2 ,, ,,
Lymphocytes and mononuclear cells	10 ,, ,,
Macrophages	55 ,, ,,

The functional signs are not marked, dyspnœa rapidly diminishes, there is little hæmoptysis, and the temperature comes down in a few days.

The absorption of the effusion takes place without thoracentesis in from fifteen to twenty days ; and if thoracentesis is performed, on the tenth or twelfth day, no fluid is obtained : the patient recovers rapidly, and the immediate prognosis is excellent.

2. *The effusion persists, increases, or recurs.*—Various clinical types are possible :

(*a*) In some cases, the effusion, which appears to be slight during the first few days, steadily increases in amount. Aspiration shows that a fibrinous exudate has been added to it.

(*b*) In other cases, the effusion persists, and appears stationary ; if aspirated, it reappears. The improvement in the general condition, which at first is rapid, ceases. The patient constantly experiences a certain amount of discomfort in the chest and the slightest effort provokes dyspnœa, which may return in slight crises during the night, without apparent cause. The patient is not suffering acutely ; his condition certainly is not comparable to what it was at the onset, but all the same he feels that he is unequal to any form of

exertion or effort. Fever, which had disappeared about the fifth or sixth day, becomes intermittent, lasting for eight or ten days together without apparent reason.

In discussing the pathological physiology of hæmothorax, we mentioned that its development is often accompanied by an exudative pleural reaction, which may either remain slight or become acute : hence the distinction rightly drawn by Dupérié between hæmothorax with secondary exudative pleuritis, and hæmothorax with sero-fibrinous pleurisy.

HÆMOTHORAX WITH SECONDARY EXUDATIVE PLEURITIS.—The effusion, which appears stationary during the first few days, instead of diminishing in the normal way, slowly increases in amount to some extent. The fluid, withdrawn by aspiration, which was at first in all respects comparable to that of a simple hæmothorax, undergoes certain changes.

We recognise, in fact, that we have to deal with a lightly fibrinous exudate, which is gradually added to the blood present without interfering with its absorption. This added fluid, which slowly replaces the hæmothorax, is, as we know, the product of the reaction of the pleura to the blood which has been extravasated into it.

The following is a typical case :

Gill. . . ., penetrating wound of left side chest, by shell fragment, on August 23rd, 1916. Hæmothorax developed, and fluid withdrawn on the following day was hæmolysed and incoagulable, containing 74 per cent. of neutrophile polymorphs, which increased to 80 per cent. by August 29th ; hæmolysis was also more marked.

From September 1st to 9th, hæmolysis diminished, the supernatant serum contained bile pigments, and the precipitate of red corpuscles was less. A fibrinous reticulum appeared in the supernatant serum. The polymorphs present during the earlier stages were replaced by eosinophiles (25 per cent.) and macrophages (32 per cent.).

On September 16th, the effusion consisted simply of coloured serum which coagulated on standing.

Here the absorption of blood and fluid was rapid, since in three weeks nothing remained but a few red cells in a small quantity of sero-fibrinous fluid. Sometimes the absorption of the blood is not so rapid, although no other complications occur. The general condition improves fairly quickly, although the temperature rises with the pleural reaction, remaining above normal so long as fluid is present, but rarely exceeding 101°. It is sometimes necessary to aspirate more than once, as the fluid is re-formed. Gradually, within a month or six weeks, normal conditions return. Occasionally a certain amount of difficulty in breathing may persist for some time, but it would appear that in the great majority of cases no serious pleural sequelæ are to be anticipated; X-rays are of great value in this connection.

Hæmothorax with Sero-fibrinous Pleurisy.—These cases are only distinguished from the preceding by the intensity of the sero-fibrinous reaction which rapidly takes the place of the hæmothorax. Obviously various grades may occur, which are intermediate between the two types which we have distinguished. But since the cytological changes in these effusions tend rapidly towards the predominance of lymphocytes, while the temperature may remain intermittent for a long period and the general condition is affected for a considerable time, some suspicion of a secondary tuberculous infection may be aroused.

Traumatic Tuberculous Pleurisy.—Dupérié has studied and carefully analysed a series of such cases. Like him, we have not accumulated sufficient data to come to a definite conclusion, but hitherto nothing in the cases we have observed has given us reason to suspect that these effusions are tuberculous in origin. These cases have often had to be kept in hospital for long periods: the sero-fibrinous effusion has re-formed, and necessitated aspiration on two or even three occasions before the signs of fluid in the pleura finally dis-

appeared, after which the return of the temperature to the normal, the excellent general condition, and gain in weight all point unquestionably to complete recovery.

3. *Recurring Hæmolysed Effusions.*—We have seen two typical cases in each of which there was a large hæmothorax, with high temperature, and a serious general condition at the outset. Aspiration on the first occasion gave incoagulable, hæmolysed blood-like fluid. An effusion of the same character was repeatedly re-formed; it remained incoagulable, with no suggestion of a fibrinous reticulum, and was also hæmolysed, as though the pleura, while able to transude an albuminous serum comparable to that of a hydrothorax, were incapable of absorbing the effusion, in which the red cells present were steadily being destroyed. In one case we withdrew 8 litres of fluid during a period of three months. The temperature rose at intervals to 102° or 103°, and remained there until the fluid, amounting to about 1,000 or 1,500 c.c., was evacuated. As the white count showed a large percentage of polymorphs, the possibility of suppuration or an infection of low virulence was frequently suspected, but the absence of any growth in cultures from the serum discouraged any surgical interference. These patients recovered completely; one of them, after four months at the base in hospital and at the depot, has been able to return to the front.

CHAPTER III

ASEPTIC SURGICAL COMPLICATIONS OF WOUNDS OF THE PLEURA AND LUNG

Of the chest cases which arrive at a field hospital, a large majority pursue an uneventful course.

In 20 per cent. of cases, however, complications of various degrees of gravity may occur. These consist either in the exaggeration of a normal symptom like hæmoptysis or pleural effusion, or in the appearance of exceptional phenomena, or thirdly in traumatic lesions of adjacent structures, caused by the projectile. Such complications are described as mechanical or aseptic.

Complications may also be produced by the introduction of bacteria into the wound. These complications are referred to as infective, and will be considered in a separate chapter.

Hernia of the Lung and Pneumatocele.—Among the complications of chest wounds which have been described, there is one which is never seen in military surgery, viz. hernia of the lung. It seems probable that the nature of the traumatic agent is responsible for this. Hernia of the lung is only possible with a long and narrow wound, such as is produced by edged weapons. In modern warfare, injury by cold steel is exceptional, and the edged weapon may practically be said not to exist. It is therefore not surprising that among a large number of chest wounds we have not encountered a single case of hernia of the lung.

We once saw an example of a rare type of protrusion of the lung outside the ribs, but the pleura was intact,

and the condition was therefore a *pneumatocele* rather than a true hernia of the lung.

In this case a rifle bullet had struck the chest wall at an angle. The impact tore away a piece of rib, about 10 centimetres long, without injuring the pleura, this being plainly evidenced by the fact that the patient developed acute sero-fibrinous pleurisy, which necessitated immediate aspiration, but subsequently subsided.

The thoracic wall was extremely thin over the whole area of the wound, and the lung bulged through it as a regular oblong tumour, which was increased on exertion; it subsided during inspiration, and consequently changed in volume with each respiratory movement.

Exceptional as they are, these cases are worthy of description.

Hæmorrhagic Complications.—These are by no means rare. Undoubtedly hæmoptysis and hæmothorax are almost universally present in wounds of the lung and pleura. They may, however, give cause for considerable alarm, either by assuming serious proportions at the outset, or by their recurrence, or by their appearance at a later stage.

1. **Secondary or Delayed Hæmoptysis** is a totally different thing from the initial hæmoptysis. The latter occurs in 80 per cent. of cases, is moderate in amount and ceases spontaneously about the third or fourth day. At the same time, sometimes hæmoptysis may recur later, when there is every reason for supposing that it has ceased for good.

(*a*) This complication usually appears about the fifteenth or twentieth day after the injury, and is sometimes so profuse as to cause the patient's death. It is nearly always produced by violent effort or strong emotion—some condition, in short, which causes a sudden increase in the blood pressure and the force of the heart-beat, and thus displaces the clot from the wounded vessel which it is plugging. We have seen

hæmoptysis recur on the occasion of an unexpected visit from the patient's father, and also during a bombardment of the hospital.

The following story is as convincing as it is dramatic. Two chest cases had arrived at a divisional ambulance, and were lying in adjacent beds. Their condition was so serious that it had been impossible to send them farther down the lines. They improved gradually. In neither case was the effusion sufficient in amount to require aspiration. The relatives had been informed that the patients were well on the way to recovery. They had been in hospital a fortnight, when, one morning, the village was bombarded: gradually the range lengthened, shells fell around the mill in which the ambulance was installed; one burst in the court facing the room in which the two men were lying. A few moments later, both had a recurrence of profuse hæmoptysis, and both died that evening.

Fatal secondary hæmoptysis may occur without apparent cause. Petit de La Villéon quotes the case of a patient with a chest wound, who had no pleural effusion, but simply an area of moist râles with a temperature of 100·4°. This patient on the fifteenth day had an attack of sudden violent hæmoptysis and died in a few minutes.

(*b*) Hæmoptysis may also occur as a *late* complication in wounds of the chest where a foreign body is retained. It is therefore usually after leaving the field hospital for the base that the patient, apparently cured, has such a recurrent hæmorrhage, which is due to ulceration of vessels in the lung by the foreign body embedded there. The hæmorrhage in these cases is not usually so sudden, profuse, and dangerous as in the foregoing type, and often subsides quite readily after removal of the fragment.

Hæmoptysis in the later stage is sometimes the first sign of suppuration or pulmonary gangrene (Michon, Lenormant).

Delayed hæmoptysis, however, is not always produced by an intra-pulmonary foreign body. Gross reports an example of hæmoptysis occurring more than three months after a bullet wound of the lung: it lasted five days and ceased spontaneously. The radiogram showed no intra-pulmonary foreign body. We have seen a precisely similar case.

Sergent and Lechevallier have seen it occur under the most varied conditions, once at the commencement of an inter-lobar pleurisy, twice in old chest wounds without foreign bodies; once in an old case from which the projectile had been removed.

It may be remarked that as a general rule these delayed hæmoptyses, which appear for no apparent reason, are slight in quantity and rarely dangerous.

2. **Secondary Hæmothorax** sometimes complicates the apparently normal evolution of a chest wound. This occurrence, noted by several surgeons (Baudet, Quénu, Michaux, Sencert), especially at the beginning of the war when chest cases were sometimes evacuated long distances, has been rare in our experience. We have only met with one instance in more than 500 chest wounds which we have treated.

Dufourmentel, however, reports a striking example of this complication. A man who had been wounded in the chest by a bullet a month before, had recovered in an apparently normal way, when suddenly, without apparent cause, his temperature went up to 103°, respiration became short and laboured, the pulse-rate increased to 130, and the expression became anxious. At the same time there was a slight blood-stained discharge from the wound of entry. Hæmorrhage was at once suspected; the thorax was accordingly opened, and the lung was found to be still bleeding; the bleeding point was secured and the patient recovered.

This recurrence of hæmorrhage appears usually to be brought on by some sudden movement of the patient,

by exertion, or by the jolting of a vehicle during his evacuation. Pierre Duval has reported a typical example. In some cases, a mistake in treatment has been recognised as the cause. Hæmorrhage has been produced, for instance, by withdrawing too large an amount of fluid from a hæmothorax of several days' standing. Aspiration reduces the pressure on the lung too rapidly; the lung expands, and the clot which is plugging the wound is displaced, with the result that hæmorrhage recurs.

Subcutaneous Emphysema is again a somewhat rare complication in war-wounds of the chest, which is not found in more than about 30 per cent of cases. It is generally limited and localised, rarely spreading beyond the limits of the injured side, but in some cases it assumes enormous proportions, even affecting the superficial tissues of the entire body.

Having regard to the mode of production of subcutaneous emphysema, it will be evident that this condition can only result from a chest wound where the thorax is closed. When air can easily enter and pass out through the wound, it cannot be forced into the subcutaneous tissues.

It is perhaps more common to see general emphysema begin as an infiltration of the mediastinum, with subsequent extension to the subcutaneous tissues. This condition may become extremely grave. The onset is sudden; the patient suddenly begins to show signs of asphyxia, he becomes distressed, struggles for breath, becomes cyanosed, and suffers acutely. Shortly afterwards the base of the neck swells up and becomes infiltrated with air, and pressure on the skin causes crepitations. In a few hours the subcutaneous tissues of the whole body are invaded, and the emphysema is general.

Hartmann describes three such cases which were treated by Gatellier and Barbary: two of these patients died, in spite of the fact that numerous incisions were

made to allow the escape of the air. This result illustrates the gravity of the condition.

Valvular Pneumothorax is so serious a complication that as a rule such cases do not get so far as the field hospitals. If they do not die immediately, they are kept at the aid post or advanced dressing station. Of the 500 chest cases which we have treated in field hospitals, only two exhibited valvular pneumothorax.

This complication may be produced by the direct escape of air from the lung into a pleural cavity where there are no adhesions. It cannot be produced unless the air can pass in only one direction, *i.e.* into the pleura during inspiration, and conditions are such that its expulsion during expiration is impossible.

It is even commoner for the air to enter by the external wound. In such cases the latter is usually narrow and irregular, and its edges are so disposed that they form a valve. With each inspiration, air enters the pleura. The pressure in the pleural cavity is increased, and the patient, conscious of difficulty in breathing, makes a greater effort, with the result that a further quantity of air enters the pleura, and his distress increases. He becomes agitated and makes desperate efforts; more air still enters and cannot escape. The more he breathes, the more suffocated he becomes.

Fractures of the Bones of the Chest Wall are so common that they are only regarded as a complication of chest wounds when fragments are displaced and driven in by the projectile, or if infection at the seat of fracture occurs.

Although occasionally the injured bone is simply perforated by the projectile, much more commonly it is actually shattered, and each fragment or splinter acts as a projectile and penetrates the pleura, or even the lung.

The various bones of the thorax are not, however, affected in the same way by the impact of a projectile.

The *sternum*, consisting chiefly of cancellous tissue

between thin layers of compact bone, has a tendency to break up into penetrating splinters. If shattered by a foreign body, it is reduced to extremely fine debris, or bone dust, which is forced a short distance into the chest.

Similarly the *scapula*, lying immediately over the ribs, is broken up into fine lamellæ, but these usually remain embedded in the muscles which are attached to the two surfaces of this bone. They are not, in fact, much displaced, and even were they to penetrate farther they would be brought up by the inner wall of the thorax. In thirty-one cases where injury to the scapula was specially noted, we found either simple fracture of the bone, comminution with splinters forced into adjacent structures, or sometimes, though rarely, a punched-out hole.

The clavicle and ribs behave in a different way.

When the clavicle is fractured by a high-velocity bullet at short range, or by any larger projectile of considerable penetrative force, it is broken up into an infinity of small needle-shaped splinters, which bury themselves in the neighbouring tissues, and become lodged amongst the adjacent nerves and vessels, or even penetrate the apex of the lung above the first rib or through the first intercostal space.

The ribs certainly form less abundant, but equally sharp, fragments, and, on the other hand, their close relation to the lung explains why splinters from them are so commonly found embedded in the pleura or in the lung itself.

The lung, moreover, is not the only structure which can be injured by the penetration of these splinters. The intercostal muscles are, of course, often lacerated, and the intercostal artery, with its accompanying vein and nerve, are often injured. But the hæmorrhage from these vessels is rarely serious, and it is very rarely necessary to interfere for the arrest of hæmorrhage from them (Michon).

It seems probable that usually the artery or vein is stretched by the projectile, and spontaneously obliterated, so that no hæmorrhage takes place; at the same time the intercostal artery may be cleanly severed by a piece of bone, and hæmorrhage result (see p. 709).

Bone fragments from the ribs more commonly cause injury to the lung than to the intercostal vessels. They penetrate the lung tissue with the shell fragment, but usually are not buried so deeply; sometimes the projectile will pass clean through the chest, while the fragments of bone remain embedded in the lung. Sometimes only the fragments penetrate the chest, the projectile which has caused the fracture striking the chest tangentially, or, in the case of large projectiles, such as the base of a shell, striking directly and then falling to the ground.

But, whatever their mode of propulsion, these bone splinters often produce serious effects in the lung. During their actual penetration, they produce serious lesions of the lung tissue and the vessels which it contains, and later, even though they may not carry infection in with them, an inflammatory reaction is produced around them, which may go on to suppuration. It is not exceptional to find splinters from a fracture of one of the bones of the chest wall in the middle of an abscess of the lung.

The complications produced by these bone fragments which have in their turn become projectiles, if they are not precisely diagnosed, owing to the fact that their symptoms are confused with those of the pleuro-pulmonary wound, may often be at least suspected. Sometimes, however, the surgeon devotes his attention exclusively to the pulmonary injury, and disregards the parietal wound. He assumes that the pleura or lung is responsible for the threatening sepsis which appears, and neglects a fracture of the scapula or ribs, whose importance and gravity he fails to understand

or disregards. We have, in fact, seen cases where there was an infected comminuted fracture of the scapula, and aspiration had been repeatedly attempted with a zeal which, if not misplaced, would have been commendable, on the assumption that a collection in the pleura was responsible, whereas the seat of fracture was the cause of all the symptoms.

Similarly, when the pleura suppurates—and it always suppurates in the neighbourhood of an infected fracture of the ribs—repeated dressing and irrigation of the pleural cavity may often be continued indefinitely without in any degree reducing the sepsis. This would, however, entirely disappear if the pleura were ignored for the time being, and the seat of fracture treated by wide exposure and removal of the bony fragments and free drainage of the track.

Involvement of Neighbouring Structures.—It is neither our intention nor within the scope of this work to study associated injuries of other serous cavities. But cases of this kind are far from uncommon. The damage caused by a shell fragment or bullet which injures the pleura or lung is not always limited to these organs. It often penetrates farther; the pericardium and the heart, the medullary canal and the cord, the diaphragm and the intra- or extra-peritoneal viscera may be injured. The gravity of these cases, as a rule, is not the result of the pleural or pulmonary lesion. If the patient does not succumb within some minutes or hours, the principal symptoms are generally spinal, cardiac, or abdominal.

At the same time, the importance which the surgeon should attach to each of these elements will naturally vary with the individual case.

Wounds of the Cord, unless complicated by rapidly fatal spinal meningitis, pursue a slow, though ultimately fatal, course. The surgeon must not on that account neglect the chest wound. He must watch the hæmoptysis or hæmothorax which for the moment

dominate the clinical picture and constitute the chief immediate danger. The prognosis is undoubtedly bad, but the patient may live for weeks, or even indefinitely as a bedridden invalid.

The Lung and the Heart may be injured simultaneously, and in such a case death is almost always immediate. The exceptional cases of cardiac wounds which have been recorded are always, as in Dujarier's instance, cases operated on at the base for sequelæ of chest wounds. Precordial distress, a rising pulse-rate, and easily produced dyspnœa attract the attention of the surgeon, and a radiogram shows a projectile in the region of the heart. Of four such cases recorded since the outbreak of the war (Vouzelles, Beaussenat, Dujarier, Chauvet) two died.

In some cases the myocardium does not seem to be involved, or, if it is, the lesion is a small one, and, apart from the phenomena produced by the injuries to the pleura and lung, the patient shows signs during the first few hours of considerable effusion into the *pericardium*. In the three cases which we have seen, this complication did not seem to have had any serious effect upon the progress of the chest wound, provided the latter remained aseptic. These cases recovered completely. Even when evacuated, however, they still complained of palpitation, of slight breathlessness on the least exertion, and of precordial distress.

The evolution of infected and suppurating wounds is entirely different. In two cases, patients whose chests had been drained for suppurating pleural effusions seemed at first to improve, but later, signs of general infection reappeared, which could not be explained after an investigation of the pleural wounds. One of these patients slowly developed serious abdominal symptoms suggestive of secondary peritonitis, and he rapidly died. The other died slowly from suppuration and cachexia. In neither case was there any clinical sign which suggested a lesion of the pericardium. It was

only at the post-mortem that—with some surprise—we discovered suppurative pericarditis.

Chavannaz also saw a case which died from an unknown cause, and in which the autopsy revealed a purulent pericarditis which had remained undetected.

Here, again, the vital prognosis depends, not on the pleural or pulmonary wounds, but on the associated lesion of an adjacent organ. Even when the patient can be evacuated, that is to say when he is well on the way to recovery, the prognosis, if the pericardium or heart is injured, is still uncertain, whereas in a simple wound of the pleura or lung it would be decidedly favourable.

Thoraco-abdominal Wounds are not uncommon, and are also extremely serious. If we accept the statistics given by Rouvillois, Pédeprade, Guillaume-Louis, and Basset, this is obvious. These authors have treated 72 cases of thoraco-abdominal wounds, and if we disregard 22 cases in which the wounds were situated on the confines of the thorax and the abdomen, and in which the signs were so slight that the surgeon considered that there was no need for interference, we are left with 50 serious cases with 46 deaths. Baumgartner recorded an excellent series of 13 cases, with 7 recoveries and 6 deaths. For our own part we have seen 59 thoraco-abdominal wounds with 14 recoveries and 45 deaths. These figures sufficiently indicate the gravity of such lesions.

When the wound involves both the chest and the abdomen, it is exceptional for the patient to present signs both of the thoracic and of the abdominal lesion. In such a case the injury is so serious that the man usually dies either immediately or at the aid post. Should he survive until he reaches the field hospital, treatment is almost always hopeless.

As Rouvillois has observed, "in some cases, the symptoms are chiefly thoracic, and these do well." The 22 cases quoted above as recovering without

surgical intervention were of this type. Our 14 recoveries were also in this category. It would appear that in these cases the abdominal lesion is slight, as far as it exists at all. It is possible, of course, for the projectile to traverse the diaphragm, and come to rest in the sub-peritoneal cellular tissue without injuring any important structure, or at all events without injuring any of the hollow abdominal viscera.

Further, it is well recognised that wounds of the lower part of the thorax are often associated with a pseudo-peritoneal reaction.

This condition has been thoroughly studied by Marcel Maillet, who describes it as the "*Syndrome-phréno-diaphragmatique.*" It is met with quite frequently.

These cases at first arouse the impression that they have a severe abdominal lesion. They complain of paroxysms of abdominal pain; and the abdomen is rigid. The respiration is rapid and shallow, hiccough and vomiting follow, and even, as we have observed, temporary obstruction, no flatus or fæces being passed. There is tenderness on palpation, particularly over the costal attachments of the rectus muscle, and along the borders of the false ribs, in fact over the whole of the lower border of the thorax. The projectile, however, is not in the abdomen. It may be said that in these cases the wound is more thoracic than abdominal, and the prognosis is that of a chest wound. These alarming symptoms disappear in a short time; in two or three days at most improvement sets in, the pain diminishes, vomiting stops, flatus is passed, and the general condition improves enormously.

In another class of thoraco-abdominal injury, the symptoms are typically abdominal; in these cases the prognosis is bad, the principal signs being those of peritoneal reaction.

The prognosis becomes that of an abdominal wound, which in war surgery is always bad, but still worse in

this type of case, owing to the chest lesion. We need not, therefore, wonder at statements by Rouvillois, Pédeprade, Guillaume-Louis, and Basset, to the effect that in seventeen cases where there were indications sufficient to justify intervention, this intervention was abdominal in every case. Our own cases have led us to precisely similar conclusions, and we can confidently assert that in thoraco-abdominal wounds, if the lesion gives rise to both abdominal and thoracic signs, it is almost always fatal, and the condition of the patient is so serious that surgical interference would have no other result than to hasten the fatal issue. No one who has conducted autopsies on such cases can hold other views. The lesions are often such that operative repair of the injuried parts is impossible.

If the injury gives rise chiefly to thoracic signs, and the abdominal signs are not marked, the prognosis is that of a chest wound, but certainly rather more grave.

If the immedate signs are chiefly abdominal, and the thoracic signs slight, the prognosis is that of an abdominal wound, with all its grave possibilities.

CHAPTER IV

MEDICAL COMPLICATIONS OF WOUNDS OF THE PLEURA AND LUNG

A PLEURAL hæmatoma, as we have already pointed out, may develop simply, without associated inflammatory phenomena. In this connection the part played by the effusion, which produces collapse and immobilisation of the lung, is an extremely useful one. But in addition to these cases there are others, which in our experience are less common than other authors suppose, in which inflammatory phenomena appear, either in addition to and complicating the gross lesion caused by the projectile and subsequent hæmorrhage, or localised in another part of the lung, or in the opposite lung.

The pleura is more commonly affected than any other structure. It reacts very readily, for reasons which we have already explained.

Various clinical types of these diverse reactions or inflammatory lesions are met with.

1. **Localised Congestion.**—Sometimes in the period immediately following a pleuro-pulmonary injury, more commonly when there is no hæmothorax, or only a very small one, areas of congestion appear in the region immediately surrounding the track of the projectile. This process can be distinguished from a primary hæmatoma by the fact that it usually causes a rise of temperature, a return of the cough, which is drier, and pain, which is sometimes, but not always, localised. The sputum becomes more abundant,

mucous, and frothy. Percussion is of little value, but the fact that a new focus is appearing is revealed on auscultation, when fine moist râles and slightly marked diffuse bronchial breathing are usually audible. This condition clears up rapidly and has no deleterious effect on the general evolution of the wound.

In some cases, the area affected is remote from that injured by the projectile. We have seen several examples, of which the following is typical:

There was a "through-and-through" wound on the lateral aspect of the left side at the level of the 5th space, with slight hæmothorax. On the sixth day an area of localised congestion appeared at the apex on the same side, the temperature rising to 102·2, with pain in the side, etc. On the next day the temperature began to fall, and in five or six days it was normal; the signs at the apex also disappeared, though rather more slowly.

2. **Massive Pulmonary Congestion.**—We have seen five cases in which massive pulmonary congestion of a subacute type developed in the injured lung almost immediately.

The patient on arrival presents the usual appearance of a chest case of moderate severity; the clinical picture is complete:—dyspnœa, cough, blood-stained sputum, thoracic pain, and a temperature between 101° and 102°. On examination on the second or third day, the physical signs suggest a hæmothorax of moderate degree. Aspiration may be delayed for several days, but even if resorted to at once it will not yield more than 1 or 2 cubic centimetres of blood-stained sero-fibrinous fluid, which coagulates spontaneously. This suggests a localised hæmothorax, or a cavity shut off by a clot, but aspiration still gives no result, whatever the calibre of the needle or trocar employed, or the point at which it is introduced, or even if two needles are introduced at the same time, as in Mosny's method for encysted pleurisy.

A careful re-examination of these cases, however, shows that there is a certain amount of variation from the usual signs of hæmothorax, although the latter are not, of course, absolutely invariable. The upper border of the area of dullness is never clearly defined ; the respiratory murmur is usually entirely absent at the base, but rather higher up slight bronchial breathing can be heard, with fine râles on coughing. Most important of all, the *coin test* is always negative. The temperature often remains in the neighbourhood of 102° for some days, and usually falls steadily but very slowly ; sometimes it becomes normal more rapidly.

The pulmonary signs persist for a considerable time, and twenty or twenty-five days will elapse before respiration becomes normal. The general condition is affected to some extent ; some cases remain in a comparatively weak condition for a long time, others, on the other hand, seem to be totally unaffected, and in this respect there is wide individual variation. However this may be, all the patients we have seen with massive pulmonary congestion recovered completely.

3. **Early Pleural Adhesions.** — The pleura is more frequently involved in early inflammatory reactions than the lung.

In the mildest cases of pleuro-pulmonary wounds, it is extremely common to hear pleural friction sounds, which often persist until other signs have subsided.

Sometimes, however, a proliferative reaction of the pleural surfaces is set up, and extensive and early adhesions are formed. This proliferation is always a sign of the reaction of the pleura to infection, which is sometimes local, but may often also involve the lung or parietes ; the complication of which we are speaking is only one result of the numerous processes which may occur in the pleura.

As Marcel Maillet was aware, this early pleural thickening often co-exists with subacute massive congestion of the lung ; sometimes, however, the pleural

reaction clearly predominates. In the great majority of cases, adhesions develop chiefly at the base, but we have seen two cases in which they were produced at the apex.

The presence of adhesions cannot usually be detected before the fifteenth or twentieth day. It would seem, however, that they may form more rapidly than this, since we have found them post-mortem on the tenth day.

The symptoms are very vague, and diagnosis is arrived at by exclusion. The persistence of pleural signs may suggest a recurrent effusion, the temperature remains in the neighbourhood of 100°, with weakness, and dyspnœa on exertion. In aspirating, the needle is distinctly felt to be penetrating a thickened pleura.

A radiogram does not always show marked opacity.

This complication is always serious, owing to its interference with the movements of the lung, which is often pronounced.

4. **Pneumonia.**—We have already discussed the incidence of pneumonia, so that it appears unnecessary to recapitulate the post-mortem and clinical data from which we conclude that pneumonia is not a common complication of pulmonary hæmatoma (see p. 755).

We have followed two cases of pneumonia which developed in patients with "through-and-through" wounds of the lung, and in each of these the pneumonia was on the opposite side to that of the wound. One died rapidly of tetanus. The classical signs of pneumonia were present, and the diagnosis was confirmed at the autopsy.

5. **Broncho-pneumonia.** — This condition belongs rather to the complications which occur in the course of infected wounds of the pleura and lung.

It may, however, occasionally develop in cases where the pleuro-pulmonary lesion seems almost negligible.

Is a projectile or foreign body capable of causing

broncho-pneumonia ? It seems more probable that infection takes place through the air-passages. However this may be, the complication is a very rare one, although it has been said that broncho-pneumonia is the most dangerous complication of chest wounds. Chest cases seem to be as immune to these pulmonary complications as wounded men in general, in spite of the appalling weather to which they are often exposed for a considerable length of time.

CHAPTER V

TREATMENT

Death occurs so rapidly after many chest wounds that the case cannot arrive in time at the ambulance where the necessary surgical measures can be taken.

In many cases death is instantaneous, or occurs within a few minutes: for these, of course, no surgical assistance is practicable. In addition to these, a proportion of the seriously wounded who are bleeding either into the pleura, or externally, and are not in a condition to be moved, die either at the aid post or at the advanced dressing station.

These advanced posts, which are installed hurriedly in positions which are often unsuitable, are unequal, as a rule, to the demands of an operation, and even if this were not so, they are so rapidly overcrowded at the beginning of an action that neither time nor personnel admits of it. In the evacuation hospital, however, or at some corresponding point, it is usually possible to perform emergency operations.

A case is not, however, sent down as far as the field hospital until he is in a condition to stand the journey. Hence an emergency operation for hæmorrhage is rarely indicated at the medical formation where the necessary intervention is practicable.

We shall return later to the indications for an operation for hæmorrhage from chest wounds—a procedure which demands the utmost rapidity of action (see p. 797).

This question has given rise to many notable dis-

cussions. It seems somewhat pointless, however, to discuss the advisability of arresting hæmorrhage which is so profuse that death will certainly follow unless it is controlled : this is not the point in dispute.

There is no question that a vessel which is bleeding must be secured, but has one the chance of doing this in the field hospitals, which are generally placed 15 or 20 kilometres from the fighting line ?

This is the main and practical issue. Experience shows clearly that a chest case in which even slow hæmorrhage persists cannot undergo so long a journey, over broken roads, in a badly sprung car and on a swinging stretcher, without grave risk of dying on the way.

Here, again, as in the case of abdominal wounds, we must face the problem of an organised advanced surgical station, equipped with all essentials, and sufficiently near the firing line to admit of immediate operation in such cases.

Theoretically such operations should be possible at the aid post, or in its immediate neighbourhood. It is difficult to say whether they are actually possible there.

Depage certainly has established an advanced surgical post at La Panne, in open country, and above ground, in full view of the enemy. Cases of abdominal and chest wounds are detained there, about two kilometres from the trenches.

But what is possible on a narrow and quiet front may not be possible on a busy one, and further, the nearer the trenches are approached, the more difficult are lateral communications. Such advanced posts, if they are to be of service, must therefore be established in enormous numbers, which is scarcely possible.

Our point is that we only propose to consider the treatment of chest wounds under the conditions where treatment is possible, namely, at a hospital some distance from the line.

We shall describe the treatment of chest wounds according to the degree of gravity of the wound. The treatment of complications will be considered later.

CLOSED THORAX

I. Slight Cases.—For these very little needs to be done, but they must not on that account be neglected. We have already referred, in connection with the examination of these cases (see p. 62) to the immediate treatment which they require on arrival at an ambulance.

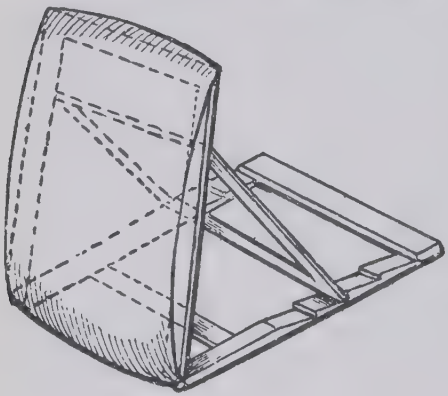


FIG. 22.

These men should be kept warm in bed. If breathing is still somewhat embarrassed, they will obtain rapid relief in the half-raised-up position. They should not sit upright, as the difficulty of respiration is immediately increased in this position, for the reason, previously referred to, that in this way the abdominal contents are pressed upwards by the thighs and interfere with the movements of the abdominal muscles and the diaphragm.

The shoulders may be supported by folded rugs or pillows, but it is much more convenient to use back-rests, which can be adjusted to any angle desired. This back-rest consists of a wooden framework, covered with a strong fabric, and hinged to a horizontal frame fitted with a rack (Fig. 22).

These cases should avoid any movement or exertion, and, as far as possible, all talking.

The treatment of cough is of primary importance

from this point of view, for every effort and every fit of coughing are dangerous. Another consideration is that coughing is painful, for fracture of one or more ribs is a common complication. It also interferes with rest. These men are weak from the discomfort of a journey, loss of blood, and the fighting and sleeplessness of the preceding days, and long for sleep, but they are awakened at very short intervals by fresh attacks of coughing.

For all these reasons, a sedative, such as syrup of codeine or morphia, is indicated.

A hypodermic injection of morphia is often the simplest and most effective treatment.

These cases may take food fairly soon. They should be put on a milk diet at first, but this may rapidly be modified, and within a short time solid food is well tolerated.

The temperature chart and the condition of the chest should be watched very carefully. A sudden rise of temperature or changes in the physical signs will often lead to the detection of a complication which would not be suspected from anything in the general condition of the patient.

II. **Intermediate Cases.**—The distinctive characteristic of wounds of this type, as Sencert put it, is the predominance of functional over physical signs.

In our experience, the extreme distress of some of these patients, their agitation, dyspnœa, and the painful sensation of air hunger of which they complain, is best relieved by a hypodermic injection of 1 centigramme of morphine. A few minutes later, the patient is no longer restless, and a physical examination can be carried out without discomfort.

Saline, camphorated oil, and hot-water bottles all help to improve the general condition.

These cases should be carefully dieted, and their food should be very restricted. In any case, they do not ask for food, at least during the first few days.

They are thirsty, but not hungry, and in this connection it is as well to place some restraint on the kindness of orderlies and the man's comrades, whom he will constantly ask for drinks. Too much fluid increases the dyspnœa and cardio-pulmonary discomfort.

All these details emphasise the necessity of isolating these cases, or still better of reserving a ward for this type of case alone. Orderlies and patients quickly get used to the conditions, and new arrivals soon appreciate the advantages of such an arrangement.

We now propose discussing the physical phenomena; the principal are *hæmoptysis* and *hæmothorax*.

Treatment of Hæmoptysis. — In cases presenting hæmoptysis it is particularly necessary that silence, as well as absolute immobility, should be enforced.

After a few hours' rest, hæmoptysis will often diminish, and finally cease. This, however, is not always so.

In the case of persistent hæmoptysis, the following mixture of ipecacuanha, in tablespoonful doses every four hours, is extremely useful:

Ipecac. Radicis	gr. i
Morph. Hydrochlor. . . .	,, ¼
Syrupus, ad.	ʒ iij

Ipecacuanha subcutaneously has also given us good results, and may be used instead of emetine.

At the same time, persistent hæmoptysis, even if very slight, should be regarded with suspicion. Such cases should not be moved, and treatment should be continued as long as the sputum contains blood, for violent hæmorrhage may occur at any time during this period.

A distinction, however, must be drawn between two types of persistent hæmoptysis. Some cases spit dark, almost black, blood for a long time, and this is

merely clot from old foci of hæmorrhage, or a pulmonary infarct which is being eliminated. Hæmoptysis of this nature tends to become darker and to diminish in quantity.

If the blood in the sputum remains bright red, the question is a totally different one. In such a case a small vessel is still bleeding, and the patient must be watched carefully, for it is in such cases as these that movement or emotion may cause sudden, and often profuse, hæmorrhage.

Should this occur, however, the surgeon should not remain inactive.

It is justifiable, in such a case, to produce an artificial pneumothorax on the affected side. We have already noted that collapse is the most effective hæmostatic for the lung, as it causes obliteration of the lumen of the vessels.

Treatment of Haemothorax in Intermediate Cases

1. The Quantity of the Effusion remains Stationary or Increases

In the cases with which we are now dealing, the quantity of the effusion is not very large. At the time of arrival at an ambulance, impaired note and bronchial breathing are rarely found above the middle of the subspinous region. But towards the fifth or sixth day, the upper limit of dullness may be at a higher level; the effusion is tending to increase. Many surgeons advise no interference with a pleural effusion unaccompanied by signs of compression, for, as a matter of fact, such an effusion is often absorbed spontaneously.

We should not be content, however, with this attitude.

Blood in the pleural cavity is an ideal medium for the growth of organisms which may be introduced into the wound, or infect it from the lung or the

adjacent parietes. If the pleura is drained, it will certainly be in a better position to resist infection, and rapidly formed pleural adhesions may often limit sepsis originating in the lung when a foreign body is retained.

If only for this reason, there is therefore every advantage in draining it.

There is no danger in withdrawing the contents of the pleural cavity : there may be harm in leaving them.

Early in this war, Phocas described a case which he had treated during the Greco-Bulgarian war, in which he operated for hæmothorax, doing a pleurotomy at once, and cleaning out the pleura. The wound was closed without drainage. "My case," he adds, "seemed to recover better than the others."

Lenormand is also of opinion that every hæmorrhagic effusion which persists should be evacuated, even if there be no rise of temperature. This mode of treatment hastens recovery, and obviates infection and suppuration of the extravasated blood.

Indications for Aspiration.—When should the fluid of a hæmothorax be withdrawn ? It is important in the first place to wait for a few days, as this period is always trying for the patient, and meanwhile the general condition improves. This delay is also valuable for the purpose of estimating the extent of effusion.

Too early decompression of a lung which has recently been bleeding risks detachment of a clot which has not yet had time to become organised. Immobilisation of the lung by a hæmothorax is from all points of view a favourable circumstance in the first few days, and obviates many congestive complications.

We have always held that conditions are most favourable for aspiration between the eighth and twelfth day.

Are there any contra-indications ? We know of none.

Some surgeons wait until the temperature shows a definite tendency to return to the normal. Fever, however, is far from being a contra-indication to the evacuation of the fluid.

Even if the evacuation of a hæmothorax which remains stationary be a questionable procedure, we believe it to be absolutely necessary to aspirate an effusion which is increasing. Here, about the sixth or eighth day, the upper limit of fluid is found to be higher than before, and as a rule the temperature rises at the same time.

The explanation of this is not recurrence of hæmorrhage from the wound in the lung, but the presence of a serous effusion, the result of reaction, in addition to the original traumatic blood-effusion. In such a case the contents of the pleural cavity should be aspirated.

The Technique of Aspiration.—A trocar of large calibre

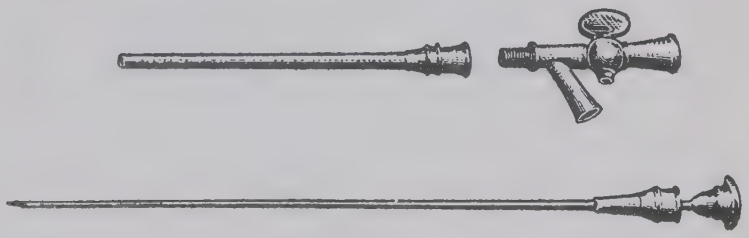


Fig. 23.

should be used. We always use trocar No. 2 of Potain's apparatus.

The position in which the patient is placed during this operation is a matter of some importance.

In some cases the patient is too weak to be placed in the sitting position. The immediate result of attempting it is vertigo, dizziness, or even syncope. This position should be relinquished at once, and the operation performed with the patient lying in the horizontal position, or with the trunk slightly raised, but in any case with the side where the needle is to be

introduced projecting beyond the edge of the table or bed (Fig. 24).

If on the other hand the patient feels no untoward effects, he should sit upright, with the legs hanging over the edge of the bed. He should rest his hands on his knees, if neither pain nor dyspnœa is produced in this position (Fig 25).

As far as possible suction should be avoided.[1] If aspiration should be too forcible, there is some risk of

FIG. 24.

suddenly decompressing the lung. The clot which fills the pulmonary wound may be dislodged and hæmorrhage recur.

Occasionally, however, no fluid is obtained, although some is obviously present in the pleura, and its presence is confirmed by a radiogram, and the point chosen is to

[1] The term "aspiration," as used in the text, is synonymous with thoracentesis, and should not be understood to imply suction. This is easily avoided by connecting a long rubber tube to the cannula and carrying its other end into a bowl of watēr on the floor—this avoids the use of an exhausted bottle and the risks entailed by suction.—EDITOR.

all appearances the right one. This failure is commonly due to the fact that the phrenico-costal sinus is filled with clot which blocks the end of the cannula. If the trocar be replaced in the cannula, and the instrument moved a little upwards, the fluid will begin to escape.

It is also well in many cases to precede thoracentesis by an exploratory puncture, which will serve at the same time to anæsthetise the region. The following technique has often been invaluable in dealing with nervous and apprehensive patients.

Fig. 25.

The Pravaz syringe which is to be used for the exploratory puncture is first filled with a cubic centimetre of a solution of novocaïn (1 in 200). This liquid is injected into the soft parts, from the skin inwards to the pleura, as far as the point is introduced. When the syringe is empty it is used to aspirate fluid which it is desired to examine from the pleural cavity. If the puncture gives a positive result a trocar is introduced at the same point—a procedure of some advantage if the effusion is a large one.

Should no fluid be obtained, there is no harm in introducing the needle at another point. Novocaïn is

only slightly toxic, and the injection can safely be repeated several times.

The point chosen should be on a vertical line dropped from the medial angle of the scapula (with the arm against the body) in the 9th intercostal space.

The skin should of course be prepared, preferably with tincture of iodine, and all other aseptic precautions taken as regards the hands of the operator and the instruments employed.

With the tip of the left index finger, the upper border

Fig. 26.

of the rib below, which in this case is the 10th rib, is taken as a surface marking. The finger is kept pressed on this point, which is where the trocar is to be inserted.

The trocar is held firmly in the palm of the right hand, the handle being well down in the hollow of the palm ; the thumb, middle, and index fingers are used to grip and direct the instrument (Fig. 26).

The needle is then rested on the nail of the left index finger, which is already in position. The skin

should not be pricked before actually inserting the needle, as this is peculiarly disagreeable to the patient.

The needle is then plunged boldly through into the pleura; the tips of the two extended fingers of the right hand act as a guard which arrests the instrument when its penetration is sufficiently deep.

The trocar is then removed from the cannula and fluid escapes. We have made a practice of evacuating the whole of the effusion in this manner, and have never seen any ill effects from so doing.

Is there any advantage in injecting air or oxygen into the pleural cavity as the fluid is evacuated, in order to avoid too rapid a decompression of the lung, and the risks which this entails? Our experience suggests that there is not: aspiration on the eighth or twelfth day, by the method described, has never caused a secondary hæmorrhage in any of our cases. The patient should, of course, remain quiet in bed, without moving for some time after the operation, but that is an elementary rule which it hardly seems necessary to repeat.

Difficulties in Connection with Aspiration.—(*a*) When the flow of the fluid is beginning to cease, there is a tendency for air to enter the pleural cavity with each inspiration. There may be no particular harm in this, but, all things considered, it is as well to prevent it, and nothing is simpler than to close the mouth of the cannula with the tip of the finger during each inspiration.

(*b*) The patient may begin to cough during the evacuation of the fluid. In this case the cannula should be withdrawn a little, for coughing is caused by contact of the point of the instrument with the lung. If, however, the cough should persist, the operation should be given up for the time being, and resumed later.

(*c*) No fluid may be obtained, although the point chosen appears to be the right one.

This difficulty scarcely ever occurs, except in the very early stages. It has, however, been known to occur otherwise. In almost every case, the explanation is that the instrument has been introduced too deeply, its point being actually in the lung. This is generally indicated by the fact that the instrument does not seem to be free in a cavity. If the base of the cannula be moved about, it is at once found that the point is not freely movable, but apparently "caught" in something; sometimes it may even rise and fall with respiration. It is sufficient to withdraw the instrument slightly, when fluid will begin to escape.

(*d*) In some cases no fluid escapes in spite of this, although the introduction of a Pravaz syringe has already shown that fluid is present. This is explained by the presence of a clot, which may be of considerable size, in the phrenico-costal sinus. Consequently the trocar, if introduced sufficiently low, has merely penetrated this fibrinous mass which cannot possibly pass through the narrow lumen of the cannula. We shall explain the procedure in these cases in dealing with recurrent effusions.

(*e*) When the effusion is not recent, but has been present for several weeks, failure of the operation is often due to loculation of the pleural cavity by adhesions. Physical examination shows a large area of dullness, but only a few cubic centimetres of fluid are obtained.

There should be no hesitation in exploring in other places with a Pravaz syringe, or even with the trocar.

A radiogram may be of great value in indicating areas where a shadow denotes the presence of further fluid adjacent to lighter areas, whence the fluid has already been withdrawn. It may even be worth while to keep the patient under the screen throughout the operation, the trocar being introduced where a shadow suggests the situation of the fluid.

2. Hæmothorax with Pyrexia

A rise of temperature very frequently occurs while an effusion of blood is present in the pleural cavity.

The rise usually occurs on the second, third, or fourth day in cases of the intermediate type. Very high temperatures may be recorded, so high as to suggest that suppuration is occurring in the hæmothorax.

As early as March 1915 it was asserted by Chavannaz that fever in a case of hæmothorax does not necessarily indicate suppuration. This rise of temperature is an effect of blood absorption, a subject of which Pillon de Nancy made an exhaustive study from the experimental point of view in a thesis which is already classical. Many surgeons, however, are obsessed by a dread of pleural infection, and consequently believe it necessary to drain the cavity immediately.

Pathological examination in these cases often shows the presence of large numbers of neutrophile polymorphs. As both thermometer and microscope seem therefore to point to pus formation, from a purely logical point of view it is justifiable to forestall the dangers of infection by draining without delay.

In practice, however, nothing could be more useless or deplorable.

A pleural cavity laid open in this way will inevitably suppurate in the end, and the surgeon will congratulate himself on having anticipated suppuration, blissfully ignorant of the fact that his own action is responsible for the infection, and its frequently serious results.

The pleural cavity should only be drained when an exploratory puncture evacuates actual pus.

Too much reliance should not be placed on pathological investigation. The indication for drainage is the presence of pus in sufficient quantity to be evident, not merely under the microscope, but to the naked eye: should its presence not be evident, the pleural cavity should not be opened, but on the contrary

closed if it has already been opened. The temperature often falls spontaneously in hæmothorax cases; it always falls after evacuation of the fluid.

3. Recurrent Hæmothorax

A third possibility is that the effusion may persistently be re-formed after evacuation. One of the writers actually withdrew as much as 8 litres of sero-hæmorrhagic fluid in such a case.

This exudative pleurisy may be the result of an infection of low virulence; or it may be induced by a clot which is lying in the phrenico-costal sinus, or, on the other hand, both of these causes may participate in producing it. However that may be, the fact remains that in these cases aspiration alone is useless; the clot must also be removed. This, at least, is what one of the writers has often found. No cannula is of sufficiently large calibre to allow of the evacuation of a clot. It is a case for the scalpel.

This *incision for evacuation*, or pleurotomy, is nothing more than thoracentesis by means of a larger opening ("ponction agrandie," see footnote, p. 868). The incision is made in the same vertical line as that used for aspiration (see p. 792), but in the 10th intercostal space, and need not be more than three or four centimetres in length.

We always use a local anæsthetic for this operation. The muscles are incised slightly above the skin incision, and the knife is passed through the intercostal space in a slightly upward direction, with the final result that the wound is an oblique one from below upwards, and from without inwards.

Farabœuf's retractors are introduced into the wound, and the fluid which then escapes is seen to contain fibrinous masses of a gelatinous appearance. Finally, the retractors are removed, and the wound closed. Owing to the obliquity of the latter, a simple dressing

is usually sufficient to close the pleural cavity completely, but if this is not so, a few sutures or bands of strapping will ensure this. The method employed is of little importance ; the essential point is that the pleura must be closed.

We have never seen an effusion re-form after complete evacuation by this method.

III. **Severe Cases.**—These are characterised by the gravity of the general symptoms, associated with marked functional and physical signs.

In these cases, everything suggests a rapidly fatal issue. The distress is extreme, the pulse very rapid and scarcely perceptible, and the face of a livid pallor. Percussion and auscultation show an enormous effusion completely filling one side of the chest. It is in such cases as these, if in any, that operation with the object of arresting hæmorrhage is justified.

This difficult problem, which was still unsolved after a long discussion at the *Société de Chirurgie* in 1911, has become one of paramount importance in view of the enormous numbers of chest wounds with which every surgeon has had to deal during the present war.

Pierre Duval, in an impressive report, based upon cases observed during the Somme offensive, constituted himself the advocate of immediate intervention in war wounds of the chest (November 1916). Rochard, Delorme, Baudet, who have long been in favour of intervention for hæmorrhage in severe chest wounds, have asked that this question should be placed upon the Society's agenda for discussion. Combier and Murat have sent a communication in which they advocate immediate operation in cases of widely-open wounds. The hæmorrhage has no tendency to cease, provided that the blood can escape freely, apart altogether from the dangers inherent in traumatopnœa.

Debeyre, Duponchel, and Arnal contribute very

important statistics of cases of this type studied under various conditions, in an evacuation hospital, a divisional ambulance, and in a Motor Surgical Unit. Duval's report also gives a clear idea of the extreme gravity of chest wounds. Of 100 cases of injury to the lung which arrived at an aid post, 30 died. Of the 70 evacuated, 25 per cent. died at the divisional ambulance. There remained 52·5 per cent. out of which 18 per cent. died at the field stationary hospital. Only 43 cases, in fact, out of 100 survived.

These statistics are alarming, and should certainly be sufficient to indicate the importance of the subject.

From Pierre Duval's figures, alone, we can draw our first conclusion. In any given number of cases which die from chest wounds at the aid post, or at the divisional ambulance, the great majority die of hæmorrhage or valvular pneumothorax.

Under present conditions, nothing can be done for the men who die at the aid posts, where treatment is a very rough-and-ready affair, even on a stationary front, and still more so in a war of movement. It is materially impossible to attempt any surgical intervention amid such surroundings.

As to those who die at the divisional ambulance, it seems almost certain that the same difficulties will be experienced as at the aid post. The equipment here is certainly adequate in quiet times for the demands of a thoracotomy; but as soon as fighting of even minor importance occurs, the place is flooded out by a crowd of wounded, and both material and personnel are inadequate to cope with them, while very often its advanced situation places it within range of gunfire, and involves the possibility of having repeatedly to shift to different quarters.

Only 52 per cent. of the cases, therefore, will reach the field stationary hospital, where an operation can satisfactorily be performed.

The number of cases dying of hæmorrhage before

reaching this stage is evidently considerable, and the attitude of the advocates of immediate intervention for the arrest of hæmorrhage is readily intelligible. Unhappily, however, the existing organisation of the *Service de Santé* and military necessities only permit of operation on the 52 per cent. which arrive at the field stationary hospital.

The question of the advisability of this operation only therefore affects these 52 per cent. of chest cases, at least at the present time. The advocates of an operation assert that intervention is a matter of urgency, because the hæmorrhage continues. No one will contest the fact in cases where the thorax is open, because, as Combier and Murard expressed it, there is no tendency for the hæmorrhage to cease.

It is a different matter when the thorax is closed. On the other hand, Pierre Duval and the interventionists regard displacement of the heart, downward displacement of the liver, and shock—in fact, the phenomena of mediastinal compression—as evidence of the continued escape of blood. Such cases as these are in imminent danger of death from hæmorrhage.

This point of view has not been accepted without question. Hartmann combined the statistics of Jeanbrau, of Maisonnet, and of Grégoire, Courcoux, and Gross, and drew the following conclusion:

"Thoracotomy, the preliminary operation for arresting pulmonary hæmorrhage, though in theory a reasonable procedure, is not well furnished with indications." On arrival at a field hospital, chest cases are no longer bleeding; hæmorrhage has been arrested spontaneously. It is important, however, to be prepared to counteract the effects of compression and shock by other means than that of operation.

The point at issue between those who advocate an operation and those who do not is more apparent than real. Nobody in reason would dispute the utility of arresting hæmorrhage which may prove fatal, or the

risk which, in a case of this type, may be incurred by an operation of even so little danger as thoracotomy, when it is well done.

Indications for operation cannot be contained within dry formulæ, such as: We must operate on serious cases because they are bleeding. We must abstain because they are no longer bleeding.

The question, put in this way, can never be answered, because both sides are right, but each for a certain number of cases only.

There are patients who are still bleeding when they arrive at the hospital, there are others who are no longer bleeding. To be content only to decompress and restore the first class would be illusory, to wish to open the thorax of those in the second category would be doing too much.

Each case presents its special indications.

When he has to deal with a severe wound of the chest, the surgeon should ask himself, "Is bleeding still going on or is it arrested?"

And here is the real difficulty. If the diagnosis of persistent hæmorrhage were easy, it is certain that the discussion would quickly cease, for no one would propose to open a thorax unnecessarily, and still less to abstain when an operation would save the patient's life.

Therefore let us consider what signs are relied upon by the greater number of surgeons who have recorded their opinions.

How shall we recognise whether a patient bleeds or no longer does so? Statistics may be multiplied, but they yield little information.

Clinical signs must be discussed rather than the results of operative or non-operative treatment.

Verily, symptoms are vague and diagnosis is full of difficulties.

Baudet asserts that the severity of general phenomena is sufficient to justify operation. So far as we

have been able to observe, it does not seem to us that the diagnosis of persistent hæmorrhage can be founded on these signs.

In the recent discussion at the *Société de Chirurgie*, we said on this question; "Shock is not always in direct relation to the amount of blood these patients have lost, or is contained in the pleura."

We have often seen patients, wounded by a transfixing bullet, who only showed signs of an insignificant thoracic effusion, and who were none the less suffering from shock. We must take into consideration fatigue, emotion, all the many accessory conditions which so peculiarly increase the primary effect of traumatism.

Many of these wounded men have been able to walk, and at the moment of being wounded have only felt a very violent blow. During the long hours of the night, they have had to make their way by communication trenches to an aid post or dressing-station. Under the influence of this effort, which is often greatly prolonged, dyspnœa becomes more marked, hæmoptysis, sometimes absent at first, comes on. Soaked through, chilled, out of breath, with rapid pulses and broken voices, they seem to be in a very serious condition. When they are allowed to rest, half-sitting up in bed, when they have been stimulated and their thirst quenched, in a few hours their colour comes back, the pulse improves, and dyspnœa quietens down.

The intensity of the general phenomena is never an adequate gauge of the severity of the hæmorrhage. But it seems that hitherto this distressing aspect of the patient has been the sole indication for operation.

Nor can more reliance be placed upon the height of thoracic dullness. It indicates no doubt that the intrapleural hæmorrhage has been profuse, but it furnishes no proof that the blood is still extravasating. Besides, it has often been remarked that compression of the

lung is the best means of spontaneous hæmostasis in this organ. Experience confirms this assertion, for a good number of cases with considerable hæmothorax and phenomena of mediastinal compression have been cured by a simple decompressive aspiration, without recurrence of the effusion.

Depage and Pierre Duval suggest that the blood-pressure should be taken every half-hour, and if it is steadily falling, that operation should be undertaken without delay. This advice is good, and this course of action may be of the greatest value. But in these cases the degree of faintness is often so marked that the pulse is scarcely perceptible, and consequently it is difficult to estimate a progressive fall of arterial tension.

Quénu has rightly insisted upon the importance as an indication for operation of the rapid increase in the effusion in the period immediately following the injury, and upon its speedy recurrence after aspiration. Whenever it is practicable this is certainly one of the best ways of learning whether the wound is still bleeding into the thorax.

Grégoire, Courcoux, and Gross have demonstrated that most valuable information may be obtained from the appearance of the effused fluid withdrawn by means of a syringe from the chest. We have already remarked, when studying the pathology of these effusions, that the blood which has escaped into the pleural cavity very rapidly undergoes marked changes. Eight, ten, or fifteen hours after the injury, fluid withdrawn by the syringe no longer presents the normal reactions of blood recently taken from a vessel.

The only one of these reactions which could be of use to us here is its loss of coagulability. It remains fluid in the test-tube, and an abundant layer of red cells separates: their hæmoglobin is presently dissolved out into the superior stratum, which is cherry-coloured, or deep red.

As to the operative indications to be drawn from these data, we may say :

If aspiration withdraws from the pleura fluid blood which coagulates in the syringe or in the test-tube, the pulmonary wound is still bleeding. It is necessary to operate.

But if aspiration withdraws fluid blood from the pleura which does not coagulate in the syringe or in the test-tube, the wound in the lung is no longer bleeding. There is no necessity to operate.

Such are, we believe, the sole means we have at our disposal at the present moment of recognising the continuation or the arrest of intra-pleural hæmorrhage.

But it must be borne in mind that, if these cases of persistent hæmorrhage are frequent at the aid posts, they are rare at the field hospital (*ambulance de traitement*). Cases which are bleeding freely can very rarely get so far. In fact, out of more than 500 cases of chest wounds, in five cases only were the patients bleeding on their arrival, but these were so nearly dead that they succumbed before we had time to help them.

When the thorax is open, the indications for operation become easier. These are the cases in which the lung bleeds, so to speak, directly on to the exterior, in which the patients drain themselves (*se vident*), to use Pierre Delbet's picturesque expression.

It is quite exceptional for persistent external hæmorrhage to come from any other source than the lung. However, Michon has recorded a case in which, on opening the wound, he found a small artery of the chest wall bleeding profusely.

Combier and Murard have clearly defined the operative indications for those cases in which operation affords the sole chance of recovery, and who would otherwise bleed to death because there is no means of limiting the loss of blood. "In these cases," said Hartmann, "it seems that hesitation is impossible,

the bleeding point must be sought for, and hæmostasis effected."

No one would dispute the necessity for hæmostasis so evidently called for. We shall return later to consider the action to be taken in these cases.

Decompression Treatment.—It consists in evacuating a certain quantity of the effusion by aspiration. This should always be done with the patient half-sitting in his bed. Too much fluid must not be withdrawn; 400 to 500 grammes are sufficient to cause the dyspnœa and distress from which these patients suffer to disappear rapidly. The drawing off of more would risk a too rapid decompression of the lung, and perhaps cause the loosening of a clot, which is still at this time a very precarious agent in the production of hæmostasis.

If, however, the effusion rapidly recurs, in spite of this precaution, then the vessel which is bleeding must be found and tied. Recurrence of hæmothorax is, certainly, one of the best indications that extravasation of blood is still going on (Quénu).

Hæmostatic Treatment.—This aims at arresting the hæmorrhage at its source.

It is obviously necessary, in the first place, to provide sufficient access to enable us to control the hæmorrhage, and treat the wound of the lung.

There is every reason for speedy action, and consequently it is well to establish a methodical routine, for every false movement, any hesitating action, may cause a loss of precious time during which the patient continues to bleed.

As the chest wall and lung are normally in contact, we may assume that the pulmonary wound corresponds to the parietal wound. The surgeon therefore may use the wound of entry of the projectile as a surface marking, which will lead to the wound in the lung.

Difficulty arises when the projectile is transfixing

(through and-through wound), for in this case there is some doubt as to which of the two wounds is bleeding. It is impossible to be certain, and it is therefore better to take it for granted that both are bleeding.

After all, if access is sufficiently free, this point of detail becomes of slight importance, because when the thorax is open it is easy to displace the lung, to draw it outside or to turn it about in the thorax, so as to bring the two wounds of entry and exit in turn under observation.

Ease in securing hæmostasis depends therefore upon good access to the wounded lung.

With this object in view, several methods have been proposed, all of which have their adherents. The method to which the operator is accustomed is always the best. To our thinking, the speediest method is to be preferred, and this may be best attained by rib resection.

Flap Method. — A U-shaped incision is made of sufficient length to include two, three, or four ribs, according to requirements (three ribs usually give sufficient access). This flap is vertical, with a hinge at the top.

Along the vertical limbs of the U, a small area of each rib is laid bare with a rugine, and the rib is then divided with the rib shears.

The intercostal spaces are then in-

FIG. 27.—First step. Marking-out the flap.

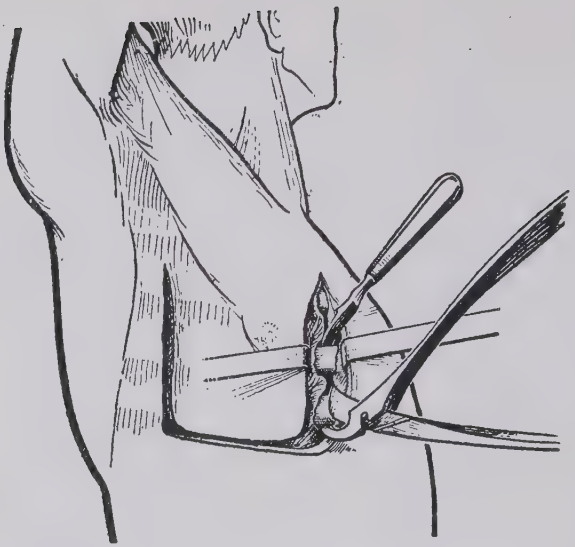


FIG. 28.—Second step. Dividing the ribs.

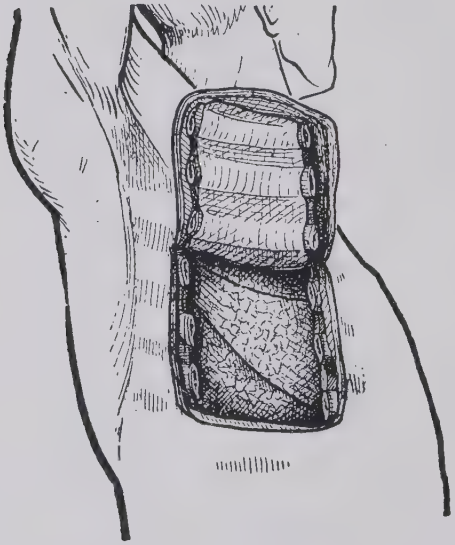


FIG. 29.—Third step. Raising the flap.

cised, taking care to apply hæmostatic forceps to the intercostal artery at the moment it is seen.

The horizontal branch of the U is incised along the middle of the corresponding intercostal space. The flap can then be raised easily.

This method has the advantage of ready access to a large area of the lung ; it renders easy the exploration of that organ, and the necessary measures for dealing with the bleeding (Figs. 27, 28, and 29).

The flap may be made over any part of the lung which it is desired to reach, hence it is usually designed to include the wound of entry of the projectile.

Resection of One Rib.—An incision 12 centimetres long is made along the rib which it is intended to remove. All the tissues are divided down to the rib, which is bared and resected over a length of at least 10 centimetres. The pleura is incised to the same extent in the bed of the rib, taking care to follow its upper border, so as to avoid injury to the intercostal vessels and nerve.

Two retractors firmly held apart by an assistant, or better, an automatic rib-spreader, will keep the wound wide open, and will separate the ribs above and below. This method gives an opening sufficient for obtaining access to the lung and for exploring the pleural cavity (Duval).

The resection is made over the spot to which access is desired. Through such an opening, the lung can easily be explored, for the whole hand is easily introduced into the chest. The lung can be brought out, turned about, or displaced so as to examine all its aspects. It will be readily understood that the resection is made on the front, back, or side of the chest, according to which surface of the lung is injured. If the opening does not seem large enough, nothing is easier in the course of the operation than to enlarge the costal resection, in one direction or the other, or to resect part of the rib lying above or below, if for any reason more space is needed.

The flap method does not give all these facilities, or at least does not allow them to be carried out with the same ease and rapidity.

To expose the upper part of the lung, the third rib

Fig. 30.

should be resected, and by resection of the fifth rib access is gained to the lower portion.

Treatment of the Pulmonary Lesion.—Whether the chest is opened by making a flap, or one is content with resecting a sufficient extent of one, or if necessary of

two ribs, this is only a means of obtaining access to the lesion, in order to treat it, and to deal with the bleeding.

The lung may be easily drawn out of the chest if no adhesions are present; but if the pleura is adherent, exploration will be more difficult, for the lung cannot be manipulated.

It is almost always fairly easy to close the wounds of entry and of exit by interrupted stitches or a purse-string suture. The ragged and torn edges of the wounds will not always bear any traction on the thread which passes through them. The surface of the organ may be so smashed up that approximation of the edges becomes impossible.

When this difficulty of suturing securely is associated with the necessity of ensuring complete hæmostasis, the wound must be packed firmly. A resistant surface is required for this to be carried out.

When the lung is adherent to the chest wall, the resistant surface is available, and further it is almost always necessary to pack these cases owing to the difficulty of suturing them satisfactorily. But if the lung is free in the pleural cavity, it is essential to fix the lung to the parietal pleura before packing gauze into the cavity.

By means of a curved needle, a mattress suture is passed through the intercostal spaces, and somewhat deeply into the lung tissue; four of such stitches (more are shown in Fig. 31) provide a ring of artificially formed adhesions, in the centre of which firm packing may be inserted.

The gauze plugs may be left in place until hæmostasis is assured, but on the third day they can usually be safely removed.

The external wound is closed, except for a small aperture which is left for the ends of the gauze packs.

A thorax opened in this way should not be drained.

The pleura should be closed completely, leaving no communication whatever with the exterior.

It will be time enough some days later to drain in the ordinary way, should the temperature, clinical signs, and aspiration indicate the presence of pus in the pleural cavity.

Fairly numerous statistics hitherto published (Delorme, Rochard, Duval, Baudet, Combier, and Murard) show that the mortality following this operation

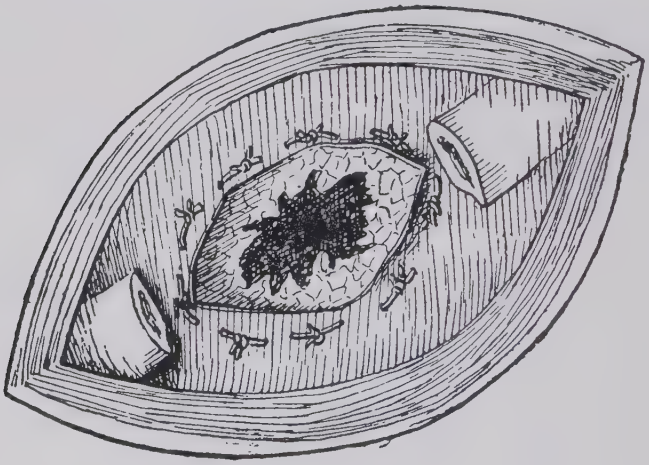


Fig. 31.

is a high one. It should not be forgotten, however, that the patients concerned are invariably in a very serious condition, and would inevitably succumb owing to a continuance of hæmorrhage if such treatment were not adopted.

II. OPEN WOUNDS

In a large number of cases, the wound of entry is so small, or the track of the projectile is so tortuous, that no actual communication exists between the pleural cavity and the exterior. This, however, is

not always so, and in 5 or 6 per cent. of cases such a communication is present.

All such patients exhibit *traumatopnœa*, in a degree depending on the freedom with which air is able to pass in and out through the wound, and therefore on the size of the aperture.

In some cases the opening is enormous.

An Engineer was brought to our hospital during the battle of Verdun ; in his back was a hole through which the hand could be introduced without difficulty and the lung be seen moving and the diaphragm rising and falling with respiration. Traumatopnœa was intense.

In other cases, the wound is small and only a slight whistling sound indicates that the pleura is laid open.

In both classes of case, traumatopnœa is a sensational rather than a serious feature ; at the same time, this communication with the exterior is an open door to infection from without. This is the factor which makes a chest wound serious.

There are, on the other hand, cases in which the communication with the exterior introduces an element of immediate danger. These are the cases in which hæmorrhage occurs in the substance of the lung.

In such cases, spontaneous hæmostasis cannot be expected. The escape of blood is unlimited, since it drains away, and it is not possible for compression of the lung by a hæmothorax or pneumothorax to arrest the hæmorrhage.

In dealing with an open wound, the surgeon is faced with a dilemma. If there is no bleeding, almost certainly fatal infection of the pleura will supervene. If bleeding occurs, the patient's life is endangered by the hæmorrhage, and in the fortunate event of its ceasing, by subsequent purulent pleurisy.

For a long time, contrary to the teaching of the old army surgeons, it was thought that this complication must inevitably be followed by infection of the pleura. In accordance with this idea, some surgeons were con-

tent with introducing a drain into the wound, whatever its situation. This was a deplorable mistake, because, if the wound is situated high up in the thorax, no drainage can take place. Other surgeons preferred to establish regular drainage at the outset in a suitable situation and to pack the wound made by the projectile.

Method of Closing the Pleura.—The practice just mentioned was soon proved to be wrong, and it was quickly realised that the pleura should not be drained unless and until it is suppurating freely. Hence the practice of routine drainage has been succeeded by that of immediate closure of the pleura. Combier and Murard, Thévenot and Dumarest, and more recently, Raymond Grégoire, Courcoux, and Gross, at the *Société de Chirurgie*, have clearly shown how much can be gained by this procedure.

If the wound is large and there is great destruction of bone, the track should be cleaned, splinters removed, and the edges of the wound excised, before closing it.

If, on the other hand, the wound is a small one, it will usually be sufficient simply to close it.

Closure of the pleural cavity merely amounts to approximating the soft parts over the wounded pleura. It is useless to attempt suture of the parietal pleura, for this is so thin and inelastic that the needle tears through, and the edges cannot be brought together.

If the wound is extensive, muscles and superficial structures may be brought together by means of interrupted sutures. If the wound is small, one or two pieces of strapping will often be sufficient to effect closure. We have never seen subcutaneous emphysema of any consequence produced in these cases.

It is possible, as has already been said, that the lung may continue to bleed, and that the blood may escape through the wound. We have already referred to these cases in discussing emergency operations in chest wounds. Combier and Murard, at the meeting

of the *Société de Chirurgie* in November 1916, contended that operation is definitely indicated, and all surgeons have supported this view, although they differ as to the desirability of surgical interference in the case of a closed wound.

When the wound gapes widely and blood escapes freely, an operation for arresting hæmorrhage and preventing pneumothorax is absolutely necessary.

The best course to pursue is as follows: resection of the fractured bones, under local anæsthesia or after an injection of morphia; enlargement of the wound to an extent just sufficient to enable the lung to be exposed and dealt with, which is usually a matter of no difficulty.

The pulmonary wound is then explored; it may possibly be as well not to attempt to clear away all the clots in it regardlessly. The edges are brought together by deep mattress sutures, or, if conditions permit, by a deep purse-string suture.

It may be asked whether it would be better to suture the lung to the chest wall, in order to prevent pneumothorax, to exhaust the air after suturing, or not to interfere with the pneumothorax at all. This discussion, in our opinion, is superfluous.

Certain surgeons, however, chary of leaving air in the pleural cavity, suture the lung to the parietal pleura. Others close the wound completely, tying the last suture after a forcible expiration, provided, of course, that the patient is not under a general anæsthetic. There are even some who deliberately introduce a trocar, after the suturing is complete, and aspirate the contents of the thorax by means of Potain's apparatus (Quénu).

There is no denying that such procedures are logical. Nevertheless they are probably not essential. Air in the thorax, if left there, is absorbed naturally, and it is a somewhat dangerous procedure to distend the lung rapidly while hæmorrhage is still a possibility,

and must absolutely be prevented, whereas the pneumothorax, which is ultimately of no consequence, will be absorbed.

"Shirt-stud" Method of Plugging.—When for any reason it is doubtful whether the pleura has not become infected, and it seems desirable to drain the pleural cavity from the first, the method proposed by M. Depage

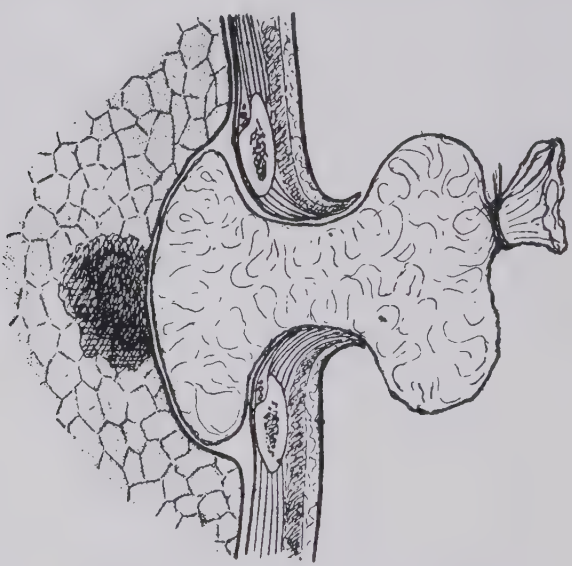


FIG. 32.—"Shirt-stud" plugging.

and termed by him the "shirt-stud method of plugging," (*tamponnement en bouton de chemise*) may well be adopted.

By this simple procedure, traumatopnœa is prevented, and the pleural cavity drained.[1] It is in fact

[1] "On empêche la traumatopnée tout en assurant le drainage de la plèvre." Personal experience does not support this statement; if the packing is sufficiently firm to prevent air whistling in or out of the wound, it is certainly an efficient bar to good surgical drainage. This method is valuable as a temporary measure between the line and the casualty clearing station, and should be reserved for this purpose.—EDITOR.

the "tent" of the old surgeons modernised and brought up to date.

The centre of a square of gauze is introduced into the cavity, so as to form a bag ; this is then packed with strips of the same material, of which the free ends are left outside.

When the bag has been packed tight enough, the edges of the gauze square are pulled outwards : this has the effect of firmly applying the bag of gauze-packing to the deep surface of the parietal wound. Then the portion of the original square of gauze which is outside the wound is made into a second bag by bringing its edges together, and this outer bag is also packed with gauze.

The outer and inner pads of plugging may readily be brought together by means of the gauze strips running from one to the other, but it is still more satisfactory to run a purse-string suture of thread through the edges of the original square of gauze, and tie it tightly over the packing outside the wound.

About the fourth or fifth day, the parietal and visceral pleuræ will be adherent, and the packing may be withdrawn.

It is exceptional for septic phenomena to appear if the patient is operated on sufficiently soon after being wounded. The wound usually heals readily, and often without the production of any subsequent effusion.

Immediate Removal of Projectiles in the Thorax

At present we only propose discussing what should be done for a patient admitted to a field hospital with a foreign body in the chest. In other words, should foreign bodies in the pleura, lungs, or mediastinum be removed immediately ?

We are not concerned in this chapter with the later treatment of a case with a foreign body in the thorax.

This question will be discussed in treating of the later sequelæ of wounds of the chest, where we shall discuss the advantages—now almost universally recognised—of removing such retained fragments. The inflammatory hæmorrhagic and respiratory complications which they provoke argue overwhelmingly in favour of their removal.

Our present problem is, however, a different one. We are now considering the case of a recently wounded man with a projectile in his chest. Some surgeons, following Pierre Duval, Rouvillois, and Guillaume-Louis, question whether immediate extraction would not be the best routine procedure, in that it would obviate the hæmorrhagic or inflammatory complications to which these foreign bodies may give rise.

The question is one of importance, and calls for serious consideration. Sencert and Legrand have already attacked the subject and have attempted to formulate the indications for immediate thoracotomy.

There is no doubt whatever that war projectiles are peculiarly liable to produce sepsis. This is a fact which the mistakes made early in the war amply demonstrated to everyone, and needs no further proof.

At the present day no one hesitates to remove fragments of metal from the deep tissues of a limb, for muscular tissue is less tolerant than any other of such invasion: the number of cases of local and widespread gas gangrene resulting from the presence of foreign bodies is appalling. All tissues, however, are not affected in the same way by the presence of foreign bodies, and by that of the micro-organisms, for the most part anaerobic, which they carry in with them. Hence we cannot endorse the opinion of Pierre Duval when he says: "Pulmonary wounds should be regarded in the same light as any other, and treated on the same general lines." Chest wounds are, in our view, in no way comparable to wounds of muscle, for example.

Lung tissue is decidedly more resistant than muscle to infection by the anaerobes which the foreign body carries in with it. It is this type of organism that occasions the extreme gravity of a war wound during the first few days. It is this type of infection which in the great majority of cases produces a condition of severe and often fatal sepsis. When the stage of aerobic activity is reached, the patient has already reacted to infection, and the prognosis is actually better.

Further, examples of pleuro-pulmonary septicæmia are relatively rare. If they were as numerous as those of septicæmia from wounds of the limbs, a consensus of opinion would long ago have decided in favour of the immediate removal of the projectile, as it has in the case of limb wounds, and the problem would no longer be under discussion.

Out of 500 cases of wounds of the chest, we have had only six cases of serious and immediate septic complications, and a foreign body was not retained in all of them.

The numbers of foreign bodies which are daily being removed in the base hospitals (*dans le territoire*), long after the date of the original wound, is a further proof of the high degree of tolerance of lung tissue to their presence. Certain surgeons have published a series of reports of these late operations: Petit de la Villéon alone contributed 58 cases, apart from others published separately. Patel gives statistics of 64 cases; Medecin-Général de la Marine Duval publishes 100 in one series, from which he carefully eliminates cases in which the projectile was located in the pleura, "whose number," he says, "would have tripled our total." It may also safely be inferred that a large number have not been published at all.

The lung is more capable than any other organ of tolerating the presence of foreign bodies and of resisting anaerobic micro-organisms. For this there is an

obvious reason :—that lung tissue, impregnated as it is with oxygen, is in the last degree unfavourable to the growth of an anaerobe.

Cases, however, undeniably occur in which the presence of a foreign body in the lung produces serious consequences. In one of our cases fulminating septicæmia caused death in forty-eight hours in spite of an extensive pleurotomy. The post-mortem showed a foreign body embedded in the middle lobe of the lung, which was for the most part gangrenous. Pierre Duval (case of Lefèvre) reports an identical example in which the foreign body had produced a cavity with necrotic walls and foul contents. But on such a question as this, conclusions cannot be reached from the consideration of a few isolated cases. In contrast to the excision of a foreign body in muscle, the removal of an intra-thoracic shell fragment is a major operation of some danger, and its influence upon the prognosis in the light of the shocked and serious general condition of the patient must be carefully considered.

A question of such importance cannot be decided lightly. Further research and more observations are wanted. Indications for operation call for closer study than mere statistics. If we were simply to say, "foreign bodies in the lung have been known to produce serious and immediate effects, therefore every foreign body in the lung must be removed at once," one can well imagine the "riot of useless and often dangerous operations, to which," as Hartmann remarks, "surgeons would be committed."

The question stands thus. Is there any particular type of foreign body which is capable by its presence in the chest of giving rise to serious complications ? It must be confessed that this is a difficult problem. At the moment of being wounded the patient shows no indication that hæmorrhagic or infective complications will supervene later. Neither the situation of the wound, nor its nature, nor the local signs are of sufficient

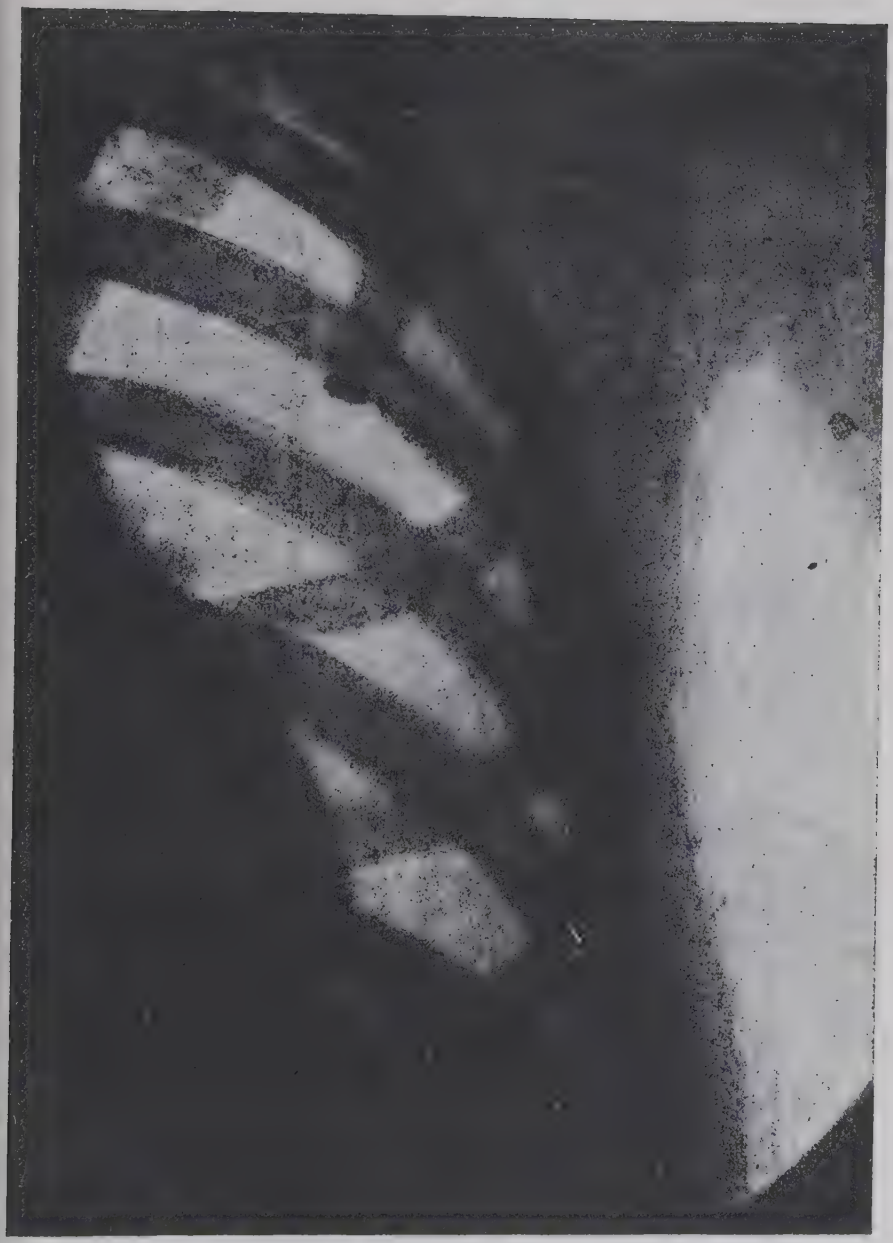


FIG. 33.—Two shell fragments in the lung. (Radiogram by Dr. Desnoues.)

prognostic value. There is little of value beyond the general condition of the patient to assist in establishing rules for operations, and cases in which the general condition is serious are precisely those in which any attempt at intervention is contra-indicated.

Sencert and Legrand present this point with admirable clearness. These patients are suffering from profound shock, and exhibit such marked physical distress that a mere trifle would appear capable of turning the scale. The state of the pulse, the pronounced dyspnœa, and general weakness give the surgeon sufficient cause for hesitation to attempt what is a serious operation, and necessarily by no means a short one.

Although, up to the present, the case for immediate removal of a retained foreign body scarcely rests on adequate grounds, yet its removal at a later date may be considered justifiable. It may be argued, that when dyspnœa has been relieved, the pulse has slowed down, and the general condition is less serious, the patient should after a few days be able to stand an operation with much less risk.

Our present knowledge of the course of infection in war wounds does not support this view. In forty-eight hours, the organisms introduced by the foreign body, or the shreds of clothing which it carries with it, have multiplied and infected the whole wound. If the tissues have been able to resist the infection, it will be localised or overcome, and surgical interference must necessarily disseminate the infection over fresh tissues, and reawaken its virulence.

But pleuro-pulmonary infection is not due solely to foreign bodies; it may spread from the parietal wound, or from bronchi severed by the projectile. Cases of through-and-through wounds, although not equally liable to suppuration in the pleura or lung, may nevertheless develop these conditions, even though no projectile is retained in the chest.

It is further to be remarked that the most enthusi-

astic advocates of the immediate removal of retained foreign bodies have themselves described cases in which the fragment could not be found, but the patient nevertheless did well, and others in which dangerous sepsis supervened, although the foreign body had already been removed.

Enough has been said to show that this problem is far from being solved, and certainly calls for further investigation.

The Treatment of Mechanical Complications

The mechanical complications of chest wounds include a certain number whose treatment need not be dealt with here. Such are fractures of the scapula, clavicle, spine, and ribs. Readers are referred to works on simple fractures, and on fractures associated with other injuries.

Treatment of Hernia of the Lung. Hernia of the lung is one of the rare complications of a chest wound, and we have only met a single case. We can therefore only repeat the conclusions of other writers as to the treatment of this condition.

The hernia may be simple; that is to say, a lobe or a small portion of the lung may bulge through the wound at each expiration, and return with inspiration. The lung "floats" in the wound. No special treatment is required for this condition, provided that the area of lung concerned is not itself injured, but if the herniated lung is bleeding, this wound should be treated as already described.

Simple hernia of the lung is quite an unimportant feature of an open wound of the thorax. Treatment should be directed to the parietal wound, and the lung left alone. The hernia will necessarily cease to exist when the wound is sutured.

A hernia of the lung may become strangulated. A piece of lung may be gripped in a narrow wound in

such a way that spontaneous reduction is impossible. It becomes congested and swollen, and these changes render its irreducibility more complete.

Later, the visceral pleura becomes inflamed and adherent to the parietal pleura, and strangulation of the hernia is complete. This is almost always followed by suppuration, or even gangrene, of the exposed lung surface.

It will obviously be dangerous in such cases to attempt reduction, since purulent pleurisy would inevitably follow.

It is therefore better to excise the necrosed tissue, or destroy it with the thermocautery.

Treatment of Secondary Hæmorrhage. — Secondary hæmorrhage may take place into the bronchi or into the pleural cavity; in other words, the surgeon may be summoned on account either of secondary hæmoptysis or recurring hæmothorax.

Secondary hæmoptysis does not always lend itself to active treatment. We have already seen that a distinction must be drawn between two types of hæmoptysis: that in which the blood is dark and scanty, and that in which the blood is bright red, and may be profuse.

The former type is merely the spitting up of a hæmatoma produced at the time of the original injury, and calls for no active treatment. The blood remaining in the alveoli is gradually ejected, and all trace of blood will disappear from the sputum in a short time.

Hæmoptysis of the second type indicates a recent vascular lesion, and calls for the closest attention; as we have already seen, it may be so profuse as to cause death.

Ipecacuanha given in large doses by the mouth is not always effective, and injections of ipecacuanha or emetine may also fail to arrest the hæmorrhage.

It is essential to keep these patients absolutely at rest; they should not be allowed to speak, and

coughing or anything else involving effort should be avoided.

Should hæmoptysis persist and remain so profuse as to cause serious alarm, the surgeon is by no means at the end of his resources.

Decidedly the best hæmostatic for the lung is its collapse. When the lung sinks back into the costo-vertebral groove, the alveoli close and are obliterated, the vessels are compressed, and their lumen, if not occluded, is at least distinctly narrowed, and further, the circulation through the lung is also diminished, since expansion during inspiration is reduced to a minimum.

Just as inspiration draws air into the thorax, so it accelerates the flow of blood into the lung from the pulmonary artery. To prevent expansion is, in fact, to reduce the circulation of blood though the lung.

On these theoretical grounds, it has been proposed to induce collapse of the lung in cases of profuse hæmoptysis by producing an artificial pneumothorax.

The procedure for this is extremely simple. There is no danger, except in haste and the neglect of aseptic precautions.

Under local anæsthesia, a small incision 4 or 5 centimetres long is made in an intercostal space, and the pleura exposed.

A small incision is then made in the pleura, through which air slowly enters the thorax. The operation is a perfectly safe one, if slowly and carefully performed.

The wound is then closed, and, of course, not drained.

Delayed hæmoptysis may in some cases be caused by the presence of a foreign body in the lung. Should profuse and repeated hæmorrhage occur in such a case, the removal of the foreign body is definitely indicated. We shall shortly discuss this question.

Treatment of Subcutaneous Emphysema.—Subcutaneous emphysema as a complication of a chest wound

does not often call for active treatment. We have already seen that this condition is relatively rare in war surgery.

Sometimes, however, subcutaneous emphysema may spread over the whole body, and give cause for considerable alarm.

Intervention is necessary as soon as the patient is troubled by the extent of infiltration, and respiration is interfered with. Even in certain cases of general emphysema, however, in which the palms of the hands and the soles of the feet alone are unaffected, spontaneous relief may occur, and the patient recover. Tuffier has reported such cases.

Multiple punctures with a needle are useful in getting rid of the emphysema.

If, however, the patient shows signs of asphyxia, stronger measures are called for. It may be necessary to make incisions to liberate the gas, wherever the swelling is most marked—that is to say, where the air is presumably escaping. In a case of mediastinal emphysema, Gatelier and Barbary made lateral supra-clavicular incisions ; but, as Hartmann observed, such incisions do not afford satisfactory drainage, since contraction of the sterno-mastoid would obliterate the valvular outlet provided in this way, and air would not escape. In another case, the same authors made a median supra-sternal incision, followed by free separation of the pre- and peri-tracheal connective tissue. This patient recovered.

In another case of this kind, in which the emphysema assumed alarming proportions, Tuffier considered the advisability of opening the pleural cavity a procedure worth bearing in mind, and of value in counteracting both the subcutaneous emphysema and valvular pneumothorax from which the former sometimes originates.

Finally, to quote Toussaint, the leakage of air which is responsible for more or less rapidly spreading

subcutaneous emphysema in chest wounds must be stopped at once. The wound may be laid widely open ; if it has been incompletely closed, and air is therefore being allowed to leak through, it may be sutured carefully, or any drainage opening through which air is entering the subcutaneous tissues may be closed.

Treatment of Valvular Pneumothorax.—Air under pressure in the pleural cavity must at once be allowed to escape. The best and most rapid means of doing this, and one of which anyone is capable, is to aspirate the affected side, through the anterior chest wall in the second or third intercostal space, with one or two needles of sufficiently large calibre, such as are used for paracentesis. The hissing sound of the escaping air clearly indicates when the pleural cavity has been reached, and the patient will be immediately relieved. At the same time steps are taken to improve the general condition, which is always very serious. Aspiration may be repeated some hours later, if necessary.

PART II

INFECTED WOUNDS OF THE PLEURA AND LUNG

CHAPTER VI

I. INFECTION OF THE PLEURA

Contrary to the general rule in war wounds, it would seem that up to a certain point the chest is peculiarly resistant to infection. One is struck by the great number of foreign bodies which remain in the pleura or lung, until they are removed in the base hospitals, and which certainly would not have been tolerated for so long a period in any other part of the body.

Out of 335 cases of wounds of the thorax which we carefully followed up, there were only 56 in which operation was necessary on account of suppuration. Again, immediate infective complications have been very exceptional; only five of our cases developed septic complications shortly after being wounded.

Evidently, in this connection, both the nature of the infection and the tissue infected must be taken into consideration.

The work of Policard and Phélip has clearly shown that nearly all projectiles carry in with them the *B. perfringens* as well as the ordinary pyogenic organisms. The *B. perfringens* is also the first to spread in the wound, which it infects more than twenty hours before the other pyococci have had time to multiply to any extent.

The *B. perfringens*, however, is an essentially anaerobic

organism, and there could be no more unsuitable medium for its growth than lung tissue, which is thoroughly impregnated with air and oxygen.

From the purely clinical aspect, we find that infective phenomena in penetrating wounds of the chest make their appearance at clearly distinct periods, and this distinction appears to us to be of great importance in studying the symptoms, prognosis, and treatment of sepsis in such cases.

Signs of infection may appear almost immediately: this may be described as primary sepsis, is invariably a serious condition, developing rapidly, and is sometimes widespread and overwhelming; in many cases it takes the form of actual pleuro-pulmonary gas-gangrene. Surgical measures have no chance of success unless undertaken as rapidly as possible.

In other cases, sepsis appears as a secondary complication, either early, *i.e.* during the first week, or later.

Early sepsis is always a serious matter.

On the other hand, sepsis which does not appear until the sixth or eighth day is often more insidious; there is some danger of its remaining unrecognised unless the patient is carefully and thoroughly examined. An operation, however, should only be decided upon after careful consideration, and should not be undertaken when suppuration is merely suspected and may not actually be present at all.

At the same time, when a chest case gives no sign of pyogenic infection during the first three or four weeks, this does not necessarily mean that the patient is out of danger, and that some form of sepsis will not supervene later, even after a very long interval. Marion found small collections of pus around foreign bodies which had been embedded in the lung for long periods, and had given rise to no clinical signs whatever.

1. Primary Infection

Pleuro-pulmonary Gas-gangrene. — Although particularly serious, these cases are in our experience happily not numerous, for, as we have already said, early septic complications developed in only five out of our 335 cases.

It will readily be understood that when sepsis develops so rapidly along the track of the projectile, it involves the lung and the pleural cavity almost simultaneously. The condition is therefore "pleuro-pulmonary" from the outset.

If the pleural cavity is shut off by old adhesions, infection may be confined to the lung tissue, but this is certainly exceptional.

Pleuro-pulmonary gas-gangrene is an extremely grave condition, but very rare.

If the injury is less than twenty-four hours old, there is nothing to indicate that this terrible condition is about to develop.

The patient arrives at the hospital seriously injured, suffering severely from shock and dyspnœa, with a feeble pulse and high temperature, already showing definite signs of more or less extensive pleural effusion.

The nature of the external wound gives no clue. A fact of great importance, however, which should always be remembered, is that the treatment usually adopted for resuscitating the patient has no effect. Dyspnœa persists and even increases, although there may not be an extensive effusion to account for it and in spite of aspiration, which would adequately relieve intra-thoracic pressure. The temperature remains above 102° and the pulse is small and rapid. The facies is particularly characteristic, having that earthy, blanched appearance typical of septicæmia, which has unfortunately become so familiar to us during the war. The mucous membranes lose their colour, the patient complains of extreme fatigue and weakness; and soon

after this, mild intermittent delirium, at first nocturnal, afterwards almost continuous, completes the clinical picture.

The local signs tell us very little. The presence of an effusion, which is not always very extensive, may be detected; the radiogram (if one can be taken) often shows a projectile in the thorax, but gangrene and septicæmia may supervene even in cases where no shell fragment is retained.

We have not found that auscultation is of any great diagnostic value. Patches of broncho-pneumonia, either in the lung involved or on the opposite side, have been recorded. In the cases we have studied, there were no signs of its presence. The dyspnœa and grave general symptoms are more often the direct result of systemic infection than of thoracic complications.

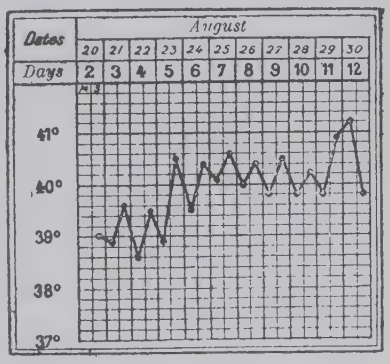


FIG. 34.

The character of the fluid obtained on aspiration varies. It is sometimes greenish grey, and from the outset its appearance and odour leave no doubt as to the nature of the organisms swarming in it.

In other cases, however, the fluid withdrawn has neither the odour nor the appearance typical of anaerobic infection; it is a serous and hæmorrhagic exudate, of a dirty cherry red colour (generalised hæmolysis) from which a deposit of red corpuscles undergoing destruction forms at the bottom of the tube, together with masses of leucocytes.

The course of this form is always rapid and fulminating; the effects of the infection are so rapidly produced that death may follow in thirty-six to forty-

eight hours. In the rapidity of its development it is best compared to gas-gangrene of the limbs. In some cases the condition develops more slowly, in eight to ten days; the chart (Fig. 34) shows the course of such a case.

Anatomical Lesions.—On opening the chest the lung on the affected side is found covered, completely or partially, by a pseudo-membranous friable exudate, irregular and vascular in surface, like a sort of whitish rind soaked in blood. Sometimes the reaction of the pleura is much less marked, and the formation of fibrous exudate is only seen on the postero-lateral aspect of the parietal pleura.

The lung, under the pressure of the effusion, is retracted on the hilum, and sometimes exhibits no changes, except those of collapse.

In a majority of cases, however, it shows extensive changes.

The injured area, which is sometimes widely open and communicates with the pleural cavity, and in other cases is lined by a friable, fibrinous, almost purulent exudate, is found to contain a projectile or projectiles, mixed up with shreds of clothing and bone splinters. The necrosed tissue, consisting of the connective-tissue framework of the lung from which a foul discharge escapes, looks like a black sponge. It is easily lacerated, and if washed in water leaves nothing but a sort of arborescent hairlike mass. This is the actual focus of pulmonary gangrene.

Sometimes the pulmonary lesions are less extensive. The track of the projectile ends in a small putrescent cavity, bounded by an area of consolidation in which thrombosed vessels can be traced.

The lower part of the pleural cavity often, but not always, contains large fibrinous masses or blood-clots. The responsible organisms in these cases are always found to be minute anaerobes, the principal of which appears to be the *B. perfringens*.

The prognosis in this gangrenous form being always fatal, by what means can it be treated ?

Can it be foreseen and diagnosed sufficiently early, and an immediate operation performed ?

The diagnosis of a gangrenous pleuro-pulmonary infection is impossible at a sufficiently early stage for surgical intervention to be of any value.

The physical signs afford no indication whatever of its onset. The composition of fluid in the pleural cavity, which might be expected to give some sign, is unfortunately an equally unreliable guide. The only test which is of value, though not always, is to sow it in Martin's glucose gelatin or Veillon's medium, both of which are particularly suitable for the growth of anaerobes. The general appearance of the patient, his high temperature, and pale, wan, bloodless face are valuable presumptive evidence, but here again a number of questions have to be decided, especially in dealing with multiple injuries, when it is often very difficult to distinguish between the effects of the various lesions.

Treatment. — It seems logical, at first sight, to suggest that the only satisfactory procedure in these cases of gangrenous septicæmia of the lung and pleura would be an immediate and rapid operation, less perhaps with the object of curing the gangrene than of preventing it.

Since the projectile or the material which it carries in with it is almost always responsible for this complication, should it not be made a routine procedure to remove them whenever they are retained in the chest ? Pierre Duval has already suggested this course.

What has hitherto very often persuaded the surgeon against the immediate removal of the projectile, is his experience of numerous cases in which shell fragments remained in the thorax without producing any ill effects, at least for a time, and the fact that serious

septic complications appeared to him decidedly exceptional.

It was rapidly and universally recognised that fragments embedded in muscle should be removed as soon as possible, but experience has confirmed the idea that, from this point of view, lung tissue cannot in any way be compared with muscle.

To quote Devic and Cordier: "Infective complications remain surprisingly rare. Localised pulmonary gangrene would occur very frequently, if the lung were no more resistant than muscular tissue, for example.

"To carry this argument to its logical conclusion, it would be necessary deliberately to open every chest which contains a foreign body."

But the removal of the projectile is only a part of the procedure indicated. It will still remain to expose the intra-pulmonary track, to resect the contused and infected tissue surrounding it, and to remove anything which may prevent its drainage.

It has therefore been questioned by many whether the extent and the dangers of the intervention to which they find themselves naturally and logically committed do not far exceed the relatively slight risk incurred by not operating. The number of cases which would have to undergo this operation is a large one, and it is an undeniably drastic and dangerous procedure, whereas the number of cases in which immediate and fatal septicæmia supervenes is small.

There is not the least doubt that intra-thoracic foreign bodies should be removed. But it is at the same time extremely important to decide at what stage it is most satisfactory to do this. Up to the present, the majority of surgeons are apparently not in agreement on the question of immediate removal of foreign bodies from the lung, as they are in the case of other tissues.

Since the principle of intervention for the prevention

of sepsis in wounds of the chest is not yet accepted—and it must be admitted that the arguments against this have a certain amount of force—the working principle must be to treat septic phenomena immediately they appear.

Unfortunately, in the very acute type of septicæmia with which we are now dealing, no course of action has been found efficacious. The progress of the condition is so rapid that the surgeon is helpless. In the few cases which we have treated, no method was successful in saving the patient's life.

2. Secondary Infection

Apart from the rare cases in which infective complications following the injury appear during the first few hours, a chest wound seems to resist infection for some length of time. Perhaps there may be an incubation phase of three, four, or five days before inflammatory phenomena make their appearance.

These phenomena are not wholly surgical. Some infective complications are purely medical, others take the form of suppuration. The latter may be localised in the pleura, or in the lung, if the pleural cavity is obliterated by old adhesions. Finally, occasionally pleura and lung are both attacked simultaneously, and it may be impossible to decide which of the two has infected the other.

Infection may be caused in such a number of different ways that it is surprising that it does not occur more often.

The projectile, and the scraps of kit or clothing carried in with it, are undoubtedly the means by which the organisms are introduced in a very great majority of cases.

This, however, is not the only way in which infection may take place. The entry of the projectile, even were it aseptic itself, causes lesions of the chest wall which are extremely liable to infection from without. In fact

it is not exceptional for the pleura to become infected secondarily to suppuration in one of the various layers of the chest wall. From this point of view, we cannot insist too strongly on the necessity for treating and watching the parietal wound, and still more the seats of any fracture of the thoracic skeleton.

It is, in fact, extremely common for a fractured rib to become infected by contact with the superficial wound, and later to infect the underlying pleura. Fractures of the sternum and the scapula are not less important from this point of view.

But just as the pleura can be infected from without, it can also be involved by an infection spreading from within outwards.

A wound of the lung only opens aseptic cavities if nothing larger than the alveoli and the smaller bronchioles is involved. Tyndale demonstrated that respired air is freed from all impurity when it reaches this point. But if some larger air passage has been injured, bronchial mucus will escape into the pulmonary wound and infect it.

Infection may also spread to the pleura from a septic focus in the lung. We have seen several cases of this.

Pathological Anatomy.—On opening the chest, the pleural cavity, which is more or less filled with pus, may be found completely free from adhesions, the lung being pressed back towards the hilum, to an extent varying with that of the effusion. A pyogenic false membrane covers and lines both the parietal and visceral pleura. This is the usual appearance of a purulent pleurisy of the entire cavity.

Much more commonly, and even in purulent pleurisy, at an early stage, the cavity is found to be divided up by thick and resistant fibrous bands, forming adhesions which are often wide and extensive, and may completely shut off parts of the cavity or connect the lung over an area of variable extent to the parietal pleura, and consequently to the chest wall.

A large variety of conditions may result from this process, and should be understood:—A single cavity, a cavity with diverticula, multiple pockets, occasionally communicating, but more often isolated, encysted pleurisy forming an isolated "pocket," either at the apex, or in the middle region, over the diaphragm, in the mediastinum, or in an inter-lobar space: any of these conditions may be found.

The parietal pleura is always thickened and covered with a whitish, often blood-stained exudate, friable and soft on the surface, and more resistant in its deeper parts, sometimes containing numbers of small circular abscesses in its substance, a condition which is most commonly seen on the diaphragmatic pleura.

The lung, which is covered by thick false membranes, often completely retracted, and sometimes bound down by bands, adhesions, or partial obliteration of the pleural cavity, either below, posteriorly, or laterally, has the appearance of a shapeless stump. The purulent cavity may communicate with the infected intra-pulmonary cavity which contains the projectile, foreign body, etc. The projectile has often dropped from the lung into the pleural cavity and it is found free, or enclosed in false membranes on the diaphragm, in the phrenico-costal sinus.

A collapsed lung often seems to escape infection from a septic pleura. Apart from cases in which pulmonary abscesses develop (suppurating hæmatoma), the histological lesions of the lung are commonplace:—collapse, atelectasis, and leucocytic infiltration through the sub-pleural lymphatics.

Lesions of neighbouring structures are of great importance. It is common for the purulent cavity in the pleura to communicate by a more or less definite and visible track with more superficial foci of suppuration, due to either costal osteitis, a lesion of the sternum, clavicle, or scapula, or suppurative arthritis of the shoulder joint, etc.

A case of Houdard's is particularly instructive: the lung was totally adherent behind, the only free portion of the pleura consisting of an antero-superior pocket, which drained through a sinus opening at the level of the arm.

Character of the Pus.—In secondary pleurisies, the conversion of the effusion into pus is sometimes so rapid that the macroscopic appearance of the intermediate stages very frequently escapes observation. Aspiration, in fact, gives definite pus.

Although methods of detecting the presence of pus at an earlier stage have been discussed and investigated by several workers, these methods of diagnosis are only applicable to fluid from a case of pleuro-pulmonary septicæmia.

The *organisms* concerned are those commonly found in wounds; any of the pyogenic cocci may be found, the commonest of which appear to us to be the *streptococcus* (which causes a particularly serious form of pleurisy), the *staphylococcus*, and the *micrococcus tetragenus*. Anaerobes are rarely responsible for this type of suppuration, except in early infections, nor do they seem to exhibit any very marked virulence or activity. The ordinary pyogenic cocci appear rather to predominate.

Symptoms.—I. **Early Purulent Pleurisy.**—A pleural infection giving rise, towards the fourth or fifth day, to purulent pleurisy may assume a very serious form.

During the first few days following the injury, the patient appears to be doing well, and the general condition improves, but this improvement is only temporary. The temperature, which was tending to become normal, begins to swing, and so rises fairly rapidly to 102° or 104°, where it remains steady. Great importance should be attached to this delayed and rapid rise of temperature, particularly to its persistence at a high level. Shortly afterwards a change in the general condition also indicates the presence of sepsis;

the patient complains particularly of malaise, a feeling of exhaustion, loss of appetite, insomnia, frequent sweating, diarrhœa ; a group of significant signs which should not escape the watchful eye of the surgeon.

There is sometimes an opening of some size into the pleural cavity which it was found impossible to close, and is now discharging a fluid which is obviously purulent. In one of Jeanbrau's cases, towards the seventh or eighth day pus was seen to be draining from the wound, and examination led to the discovery of a large intra-thoracic collection of pus. In this case, the diagnosis was easily made, but the reverse is usually the case.

None of the physical signs which distinguish an extensive effusion suggest the likelihood of suppuration. Œdema of the chest wall, which is given in textbooks as a sign of purulent pleurisy, is certainly the most inconstant and the most misleading of symptoms, and should never be relied upon.

There is only one method of diagnosing the transformation of an effusion into pus, viz. *aspiration*, and *naked-eye* examination of the fluid.

The *needle* used should be one of large diameter.

Some surgeons rightly advise making a larger opening, *i.e.* with a knife, as described on p. 796.

There should be no hesitation, should no fluid escape from the needle, in actually aspirating (*i.e.* using suction), by means either of a syringe, or such an apparatus as Potain's.

Presumptive evidence of suppuration should induce the surgeon to repeat this process as often as may be required. In spite of the discomfort which it may cause the patient, it is much better to explore with a needle unsuccessfully a dozen times than to risk overlooking a purulent collection in the chest.

It should always be kept in mind that a purulent pleurisy *may be loculated.*

A case of this kind which we followed up is worth

describing. A gunner aged thirty was struck by a shell fragment which passed through the apex of the left lung. On the third day the temperature rose, and the general condition changed. As the physical signs indicated the presence of a large effusion, it seemed probable that this was going on to suppuration. Aspiration, however, at. the usual point yielded a fairly large quantity of clear sero-hæmorrhagic fluid which was perfectly sterile. Instead of falling, the temperature remained high, and aspiration was repeated nearer the base; this again gave serous fluid containing very little blood. The whole of the apex, however, remained dull, with marked bronchial breathing. It was then suggested that the track might be surrounded by an area of traumatic pneumonia, with a sero-fibrinous reaction of the pleura. At the autopsy, however, we found a second collection, consisting of fœtid pus, which occupied the whole of the apex of the pleura and was separated by a wall of adhesions from the sero-fibrinous collection at the base.

Not only should aspiration yield fluid, but *naked-eye* examination should indicate that this fluid is purulent.

It was with the praiseworthy object of permitting operation immediately on the appearance of suppurative changes, that certain surgeons suggested a leucocyte count as a means of detecting pus formation at an early stage.

Policard and Phélip, and later Policard and Desplas, have given tolerably precise formulæ for this purpose. The cytoprognosis of pleural effusions should be a matter of no difficulty; an initial and progressive increase in the neutrophile polymorphs, which rapidly amount to 80 or 90 per cent. of the total white cells, should be sufficient evidence of the impending transformation of an effusion into pus.

But Dupérié has amply demonstrated in recent communications that this is not a sufficiently reliable sign, and we are entirely in agreement with him. For

some cases of hæmothorax infected by anaerobes, which end fatally within 48 hours, the white count indicates leucopaenia with a high percentage of mononuclear cells; cases of hæmothorax in which there was marked polymorphonuclear leucocytosis in the early stages have pursued a benign course; and cases of hæmothorax in which this leucocytosis was permanent and progressive have not suppurated; some cases of recurrent hæmothorax are striking in this respect.

The morphological appearance of the leucocytes present in the effusion seems to us to constitute a more reliable sign. In order to study this satisfactorily, it is sufficient to allow 8 or 10 c.c. of liquid to stand for some hours, when a more or less well-marked layer of leucocytes is found to have collected at the bottom of the tube; films made from this show masses of leucocytes, the altered appearance of which is of great diagnostic value. This is the first sign of pus-formation.

On the other hand, if we adopt the routine of making cultures from every specimen of fluid aspirated; the rapid growth of colonies constitutes a second important sign of approaching pus-formation.

Laboratory methods are a useful adjunct to clinical examination, but should not be allowed to supplant the latter.

We have made it a definite principle never to drain the pleura except when aspiration has given definite pus.

Evolution.—Early secondary purulent pleurisy is a serious complication, and becomes all the more so the longer it has remained undetected.

In this connection, however, a distinction must be drawn. It would appear that the gravity of the condition bears a direct relation to the time of its appearance.

Purulent pleurisy, developing within a week of the

injury, is apt immediately to assume a very grave aspect. The general symptoms rapidly become very marked; the patient loses flesh, cannot eat, does not sleep, and often suffers from profuse diarrhœa; he appears to be going downhill rapidly, and only too often, in spite of active surgical treatment, he succumbs to the infection.

Exceptions to such a result do, however, occur. The temperature chart in Fig. 35 is that of a patient who developed purulent pleurisy on the sixth day;

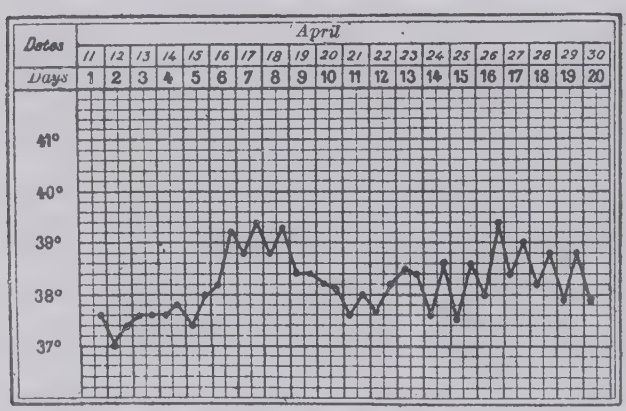


FIG. 35.

he was operated upon three days later, and recovered completely.

II. **Delayed Purulent Pleurisy.**—(*a*) This later form is characterised by the usual signs of purulent pleurisy, present in a less marked degree. It is not seen before the fifteenth to the twentieth day, and a fact of some interest is that it is often preceded by signs of localised suppuration in the lung.

We have seen three particularly striking examples of this. The following is typical of the clinical history.

A young soldier, Pierre Ch. . . ., wounded on August 8th, 1916, by a bullet, with fracture of a rib on the right

side, had all the signs of a slight hæmothorax. Towards the end of August, a patch of bronchial breathing, with fine râles which seemed gradually to become moist, was discovered in the region of the middle lobe. The sputum was muco-purulent in appearance. The focus of infection evolved slowly, and on September 15th was still present, with loud râles, bronchial breathing, and a rather smaller quantity of sputum. The temperature remained between 100 and 102° without much variation. The patient felt weak and lost flesh. A focus of suppuration was looked for, without success.

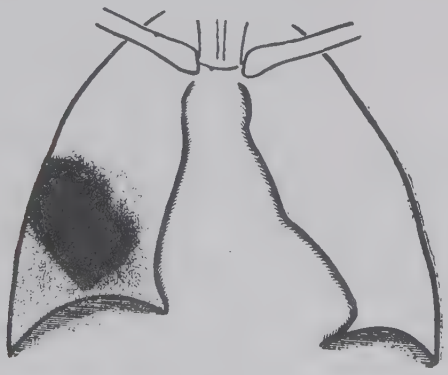


FIG. 36.

Exploratory puncture at various points only yielded a fluid which was at first sero-hæmorrhagic with a fibrinous coagulum, and afterwards sero-fibrinous. Several radiograms showed the condition indicated in Fig. 36, namely, a rectangular zone of opacity, corresponding to the area of lung involved. This zone could be distinguished clearly from the shadow of the fluid, which was, moreover, diminishing. An exploratory operation on the lung was discussed. Ten days later, exploratory puncture at the lower limit of the opaque zone yielded pus. In the operation subsequently performed it was found that the pulmonary focus had ruptured into the pleura.

(*b*) Occasionally the suppurative process takes an insidious course. The patient has a hæmothorax, the evolution of which is to all appearances absolutely benign; fever may even disappear, but the general condition is not satisfactory; the appetite is poor, the patient sleeps badly, and in the morning complains of night sweats; the weight remains stationary, or even decreases. Pus must be looked for in these cases, but its discovery by exploratory puncture will probably cause some surprise. This type of purulent pleurisy clears up in a few days after operation.

Diagnosis of Delayed Purulent Pleurisy. — The surgeon is liable to two mistakes in the treatment of an infected chest wound. He may diagnose purulent pleurisy and drain a simple sero-hæmorrhagic pleural effusion; or he may fail to detect pus in the pleural cavity and abstain from operation because he regards the physical signs and temperature as due to some lung condition. These two errors are equally prejudicial to the patient, for, in either case, death usually results.

1. With wider knowledge and experience of the evolution and clinical features of hæmothorax, the surgeon is less and less likely to mistake a hæmothorax with pyrexia for a purulent pleurisy. It is, indeed, extremely common for a rise of temperature to occur during the first few days. It usually falls again towards the seventh or eighth day, and the patient readily recovers as the effusion is absorbed.

But about the tenth or twelfth day, it occasionally happens that the fever, which was beginning to diminish, steadily increases.

At the same time the patient does not seem worse, and dyspnœa may even be decidedly less.

This is the type of case which has for a long time been misunderstood, and has given rise to such lamentable mistakes. The surgeon has taken a single symptom as an indication for operation with the

object of dealing with a supposed infection in the earliest stages of its development. Pathological reports only confirm his opinion, for it is quite common at this stage for the precipitate from the effusion to contain a large percentage of neutrophile polymorphs.

Everything, even the result of an operation, seemed to confirm his belief in the necessity for intervention, for the wound, opened and drained in this way, soon suppurated. The surgeon then congratulated himself on having performed a useful operation in good time, never suspecting that he was himself responsible for the suppuration which had occurred.

Pleurotomy for drainage should never be performed unless exploratory puncture has indicated the presence of pus in the pleural cavity.

Pleurotomy under these conditions carries with it a prognosis of the worst type. Out of nine patients treated by this method, whose case-notes we have collected, eight died in spite of the most careful attention and treatment.

2. Not less common or disastrous is the error of mistaking a suppurating pleural effusion for pneumonia or broncho-pneumonia. This mistake, in fact, is very commonly made. In certain cases it is caused by failure to obtain pus by exploratory puncture, the latter being insufficiently persisted in or badly carried out.

We need not repeat what has been said as to the extreme rarity of pneumonia localised in the injured lung.

Pneumonia may occur, but it is usually on the opposite side, and even then it is very rare. Its existence should never prevent an exploration for pus on the injured side.

Similarly the discovery of scattered patches of râles and bronchial breathing on the injured side should not satisfy the surgeon's mind.

Before establishing a diagnosis of broncho-pneumonia,

every means should be used to make certain that purulent pleurisy is not also present or even alone responsible.

II. INFECTION OF THE LUNG

All the infective conditions to which the injured lung is liable do not by any means come within the domain of surgery. In those which do, there is pus formation, *e.g.* pulmonary abscess; others, such as pulmonary congestion, broncho-pneumonia, pneumonia, are purely medical.

1. **Abscess of the Lung.** — We have hitherto held the opinion that all, or nearly all, pulmonary abscesses secondary to wounds of the lung are formed around foreign bodies embedded in the lung tissue. We do not believe that contused tissue can produce a collection of pus unless such a foreign body is present.

The nature of foreign bodies is essentially variable. Some, such as metallic shell fragments and bone splinters, are opaque to X-rays; others, as, for instance, scraps of leather, shreds of clothing, and particles of stone or wood which have entered with a projectile or have been scattered by the explosion of a shell, cast no shadow.

The character of the pus and the development of an abscess will vary according to the nature of the organisms introduced in this way.

Gangrenous Abscess.—These collections are usually formed early, *i.e.* within a few days or weeks of the injury.

The abscess cavity varies very much in size, but is rarely larger than a hen's egg or an orange. The walls are irregular and flocculent, and are generally coloured a mottled greenish grey. Shreds of necrosed pulmonary tissue suspended in the cavity are still attached at some point to its walls. Ragged pieces of lung tissue, often of quite considerable size, may even be found absolutely free and detached, suspended in

a quantity of grey putrescent fluid, in the midst of which the projectile is discovered.

The vessels appear to offer a more prolonged resistance to the advance of necrosis, and sometimes project on the wall of the cavity or even cross it. The larger the vessel, the longer it will remain intact, but ultimately its wall also necroses, and violent hæmorrhage follows. Pierre Duval quotes a case of Lefèvre's, in which, twenty-five days after the injury, the patient died in five minutes from profuse hæmoptysis caused in this way.

The pus, gangrenous débris, and necrosed walls of the abscess give off a stinking, nauseating odour as soon as the cavity is opened.

The surrounding pulmonary tissue has reacted vigorously. It is consolidated, reddish, and quite hard on section. If a piece be placed in water it falls at once to the bottom. Air can no longer enter the alveoli.

This process sometimes extends a considerable distance from the abscess. Even the pleura is affected; it becomes thickened, to an extent varying with the proximity of the collection to the surface of the lung. Usually, if not always, adhesions form between the two layers of the pleura, and the lung becomes therefore fixed to the chest wall.

Phlegmonous Abscess.—An abscess of this type develops much more slowly. Pus forms gradually, and gives rise to no signs, until eventually serious symptoms of infection make their appearance. This explains the unexpected discovery of small intrapulmonary collections of which Marion has recorded examples. In such a case, the surgeon is considerably surprised, during the removal at a late stage of a foreign body from the lung, to find a small cavity containing pus, which has been formed without giving any sign of its presence.

As in the above case, a foreign body is nearly always

present in such an abscess. Sometimes it is a fragment of shell or grenade, more exceptionally a rifle or machine-gun bullet, much more frequently a shred of clothing or a bone splinter forced into the lung by the impact of the projectile.

These collections vary in size from that of a hazelnut to that of a clenched fist, and may be even larger. We once operated for an abscess of this kind which proved to be at least as large as the head of a full-time fœtus.

The cavity is rarely regular; it usually consists of a central cavity opening into diverticula, which are separated by more or less prominent ridges. It is apparently in the areas between the larger air-passages and blood-vessels that the pulmonary tissue is destroyed or compressed by the suppuration. A section of one of these spurs or ridges always shows that its framework consists either of a vessel or a bronchus.

The walls of the abscess are covered with a thick layer of creamy pus, beneath which the lung tissue is destroyed by suppuration and is a yellowish colour.

The pus which the abscess contains is usually yellow or greenish yellow; it is thick, and gummy, and does not drain away readily during the first few days.

We have found that these abscesses tend rather to track towards the surface of the lung than to open into a bronchus. This extension towards the surface is perhaps explained by the fact that the pus follows the track of entry of the projectile or bone débris which has been driven in.

However this may be, it is not unusual for these collections to spread to the deep surface of the chest wall, and in one case of ours the pus escaped through the entrance wound. More commonly the pus spreads beneath the ribs, invading the pleural cavity, which was previously empty. Hence these collections may assume the "shirt-stud" form, with one pocket in the lung, the other spread out as a thin layer imme-

diately beneath the chest wall, and a track, of varying length, connecting the two cavities. In these cases, the seat of fracture almost always communicates with the superficial collection of pus, completing a series of cavities of varying size which extends from the external wound into the lung, in the centre of each being bone débris from the fractured rib or scapula.

Although a gangrenous abscess contains anaerobic organisms, suppuration of this type is usually produced by ordinary pyogenic cocci. The development of these abscesses, the date of their appearance, and the condition of their walls and contents are readily explained by what Policard and Phélip, Lecène and Frouin have laid down concerning the bacterial flora of war wounds.

Symptoms of Abscess of the Lung.—We have already mentioned that in exceptional cases a foreign body in the lung may give rise to a small abscess which produces no signs or symptoms whatever. Nothing suggests the presence of the abscess, and it is discovered only on the operating-table or at the post-mortem.

Fever, loss of flesh, and respiratory distress are the three signs chiefly suggestive, in a chest case, of abscess of the lung, when there is no collection in the pleura.

Abscess of the lung is rare, and is usually only formed at a comparatively late stage—the second or third week, and sometimes even later. The symptoms are indefinite and slow to appear. Sometimes the formation of an abscess is indicated by recurrence of fever, vague thoracic pain, and the persistence of occasional attacks of coughing. Later there is expectoration, which is the one really definite symptom ; the sputum is thick and purulent, slightly offensive, and usually abundant.

Physical examination will sometimes detect an area of dullness with cavernous râles and bronchial breathing ; but this is not always the case, since the abscess

may be situated at the base, where frequently adhesions or residual effusion mask the signs in the lung.

A radiogram is sometimes of value, in showing a shadow, often regular in shape, which contrasts with the relatively lighter area corresponding to the rest of the lung (see Fig. 36).

Abscess of the lung may give rise to a secondary empyema, but more commonly dense pleural adhesions exist and prevent this complication.

The clinical aspect in a case of abscess of the lung sometimes suggests tuberculosis—the signs being localisation at the apex, the evidence of cavitation, profuse expectoration, loss of flesh, and intermittent fever.

Although abscess-formation is rare, it must be borne in mind as a possibility in war surgery. No other condition gives the signs of a cavity containing pus and air, since an empyema secondary to a war wound very rarely opens into a bronchus.

The diagnosis of tuberculosis should not be substituted for that of abscess of the lung except on bacteriological evidence (see p. 880).

Evolution. Prognosis.—The prognosis and the evolution of a traumatic pulmonary abscess will vary considerably according to the type of organism present, which is equivalent to saying that they will vary with the nature and the date of appearance of the condition.

Early *gangrenous abscess*, accompanied by immediate and rapidly serious general phenomena, is a grave condition owing to the marked degree of toxic absorption which it causes. Another grave feature is the likelihood of secondary hæmorrhage. If there is a large vessel near the abscess, and the tissue around it is gradually destroyed, the chances are very great that sooner or later the wall of the vessel itself will ulcerate, causing hæmorrhage which may prove fatal.

The prognosis in the case of *phlegmonous abscess* is certainly more favourable. Should it be diagnosed

and drained in good time, the patient is quite likely to recover, but the state of emaciation and cachexia to which patients with this condition may be reduced is surprising.

It is true, however, to say that while in the first case the prognosis depends upon the organism present, in the second it depends upon surgical action. If the abscess is drained early and in the proper place, the patient generally recovers. This shows the importance of careful investigation and correct diagnosis in cases of this type.

Diagnosis. — In any chest case in which signs of infection appear during the second week, and no râles are heard on auscultation, it is extremely probable that an empyema is present, but it is also possible that a collection of pus is forming in the lung. In addition to the physical signs, exploratory puncture and X-rays are important aids in diagnosis.

Percussion and auscultation show a patch of consolidation in some part of the lung, and the introduction of a needle, often to a considerable depth, leads to the discovery of pus. But it is more particularly under the screen that the dimensions, depth, and exact position of the abscess can be determined, and it is nearly always possible at the same time to locate a shell fragment which has hitherto remained undetected, or a bone splinter or some other foreign body, situated in the interior of the cavity.

Pneumonia and Broncho-pneumonia in the Course of Pleuro-pulmonary Infections.—These complications, which, as we know, are rare in simple hæmothorax, are more common in infective conditions, particularly in association with purulent pleurisy. In the cases which we have seen, pneumonia developed some days after an operation for empyema, and was confined to the side opposite to that of the lesion. This illustrates the importance of carefully studying the physical signs before operating for empyema, in order to avoid

the mistake of referring a sharp rise of temperature to a supposed retention of pus in the pleural cavity.

Broncho-pneumonia is often a late complication in these grave cases of empyema, and one which only hastens the fatal termination.

All the cases in which we have diagnosed pneumonia or broncho-pneumonia have ended fatally.

CHAPTER VII

TREATMENT OF INFECTIVE COMPLICATIONS

THE infective complications of chest wounds more commonly involve the pleural cavity alone. They may also affect the lung only, or, more rarely, the pleura and lung together.

Such infections are not of uniform gravity; widely different degrees of severity are possible, which vary with the time at which the infection appears; in other words, there are "different degrees of virulence." Infection appears and develops with a rapidity which increases with the virulence of the organism concerned. The army surgeon soon realises that the few stereotyped means of dealing with infection which he possesses, although adequate in a certain number of cases, are quite inadequate in others. The earlier the appearance of the infection, the less likely is the surgeon's action to be successful.

A patient with a chest wound, in whom the signs of infection appear during the first few hours, is practically condemned to death, whatever steps may be taken to save him; the mortality is 95 per cent., so great is the virulence of the organisms.

When signs of infection appear during the first four days, whatever treatment be adopted, 50 per cent. of cases die.

Late sepsis alone, in which the infecting organism is of a low degree of virulence, is relatively easy to treat successfully.

At the same time, whether the evidences of infection

are of the most severe or only of a moderate type, the nature of the organism, as indicated by its microscopic appearance, is always the same, and it rapidly becomes evident that surgery is only a part of the necessary treatment, since it does not strike directly at the infective agent. This has been the object in using univalent or polyvalent sera, or metals in the form of salts or in colloid form. Experience will show whether the solution of the difficulty lies in this direction.

I. **Treatment of Infection of the Pleura.** — When the pleura suppurates, it must be drained. The indication is imperative, and it should be carried out as soon as possible. The rule remains the same, whatever the position or extent of the collection. Whether the pleural abscess be encysted, mediastinal, diaphragmatic, parietal or interlobar, or if, on the other hand, the entire pleural cavity be involved, free outlet must be given to the pus. The technique only varies in the selection of the best situation for drainage.

Apart from a few exceptional cases, no one would propose aspiration as a means of evacuating pus from the pleural cavity. Such a method, in the immense majority of cases, should be entirely avoided.

We might almost say the same with regard to simple thoracotomy. An incision in an intercostal space is quite insufficient to provide for adequate and continuous drainage of the pleura. The drainage tube is soon occluded by pressure from the adjacent ribs, and pus cannot escape. Resection of a rib is therefore essential.

Anæsthesia. — Thoracotomy for an empyema involving the *whole* pleural cavity should be performed whenever possible without a general anæsthetic. An increase in the pulse-rate, faintness, and even syncope, which may prove fatal, are by no means rare during general anæsthesia in cases of this kind. It is probable that these complications are produced by the toxic action of the anæsthetic, combined with the

mechanical effects of displacement of the heart and mediastinum by the effusion.

We therefore advise local anæsthesia in cases where the whole pleural cavity is involved. Novocaïn is so feebly toxic that it may be so freely injected as to produce absolute analgesia.

Anæsthesia of the soft parts, skin, and muscles is easily produced, but the resection of a rib is usually painful. It is possible, however, to obtain as complete anæsthesia of the periosteum and bone as of the soft parts.

When the rib has been exposed, the intercostal nerves above and below must be anæsthetised. In order to do this, the needle of the syringe should be inserted in the posterior angle of the wound, through the external intercostal muscle, and just beneath the lower border of the rib to be resected, in a slightly upward direction. The point will then pass beneath the rib, into the groove along which the intercostal nerve runs. The needle should not be pushed too far, as the external intercostal muscle at its upper attachment is very thin (not usually more than two millimetres in thickness), and this is the only structure traversed in reaching the nerve in the costal groove. One cubic centimetre of a 1 in 200 solution of novocaïn is injected for this purpose.

It is also necessary to anæsthetise the next intercostal nerve above, which also supplies the periosteum of the rib. The injection (of the same quantity) is therefore repeated, the needle being introduced above the upper border of the rib in the posterior angle of the wound, in the same manner as before.

After a few moments, anæsthesia of the bone will be complete, and the latter may be stripped of its periosteum and resected without giving the patient any pain.

In addition to this method of local anæsthesia by injection *in situ*, another, that of regional anæsthesia,

or injection of the nerves at a point some distance from the wound, is staunchly advocated by Pauchet and Sourdat. For rib-resection by this method, we are of the opinion that at least four intercostal nerves should be anæsthetised, two above and two below the rib to be resected.

Thoracotomy with Rib-resection.—The skin-incision

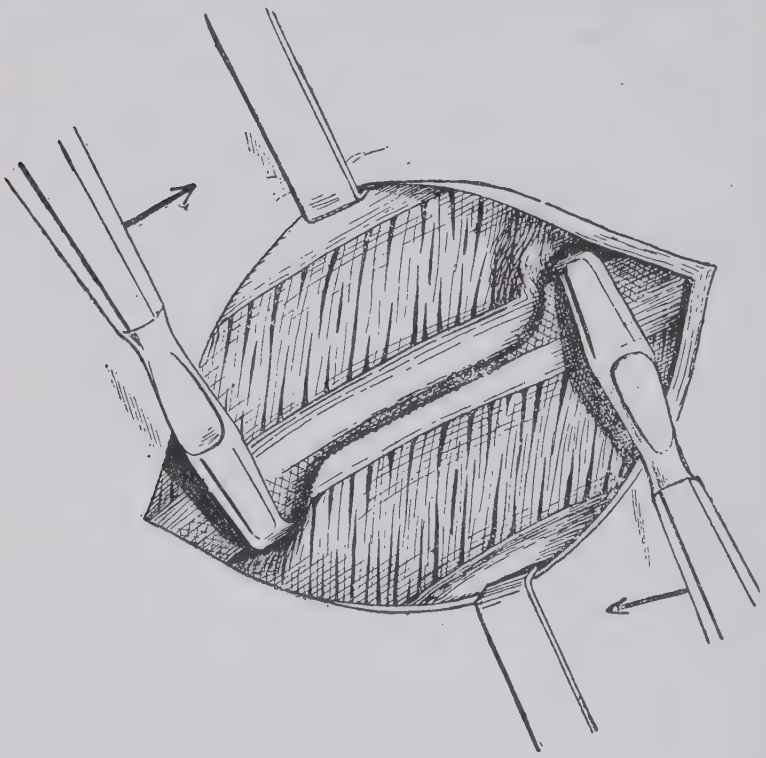


Fig. 37.

is made at a point corresponding to the situation of the collection.

It should be about 10 or 12 centimetres long, and should be carried along the rib which is to be removed.

The muscles are divided to a corresponding extent,

so as to expose the rib throughout the whole length of the wound.

Next, the periosteum is split along the whole extent of the rib exposed. The scalpel is then laid aside and a curved rugine is used to detach the periosteal sheath, and to reflect it systematically throughout the extent of the incision, first towards the lower border of the rib, then towards the upper.

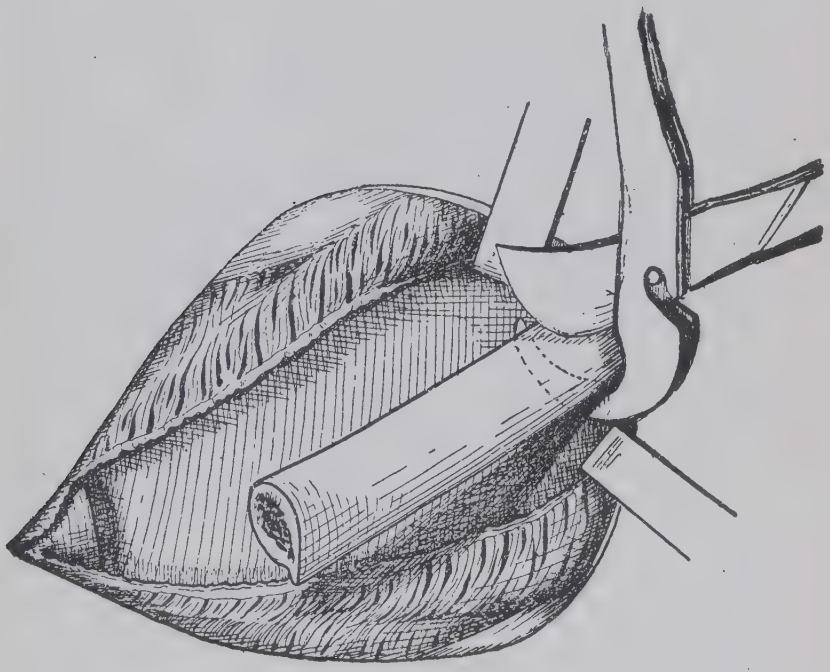


Fig. 38.

The intercostal muscles which are attached to the two borders of the rib must now be detached. This separation may be carried out with the greatest rapidity if the anatomical details of these muscles be taken advantage of. The intercostal muscles are composed of both muscular and tendinous fibres: at their attachments to the upper margins of the ribs, the

direction of their fibres is from above downwards and forwards, making an acute angle with the rib at their insertion. If, therefore, we attempt to detach the muscle with the rugine by working antero-posteriorly, the rugine will be deflected upwards into the intercostal space by the tendinous fibres which it encounters. But if, on the other hand, the rugine be inserted at the posterior end of the wound, on the upper border of the rib, it will drive into the acute costo-muscular angle, and with a single stroke detach both muscular and tendinous fibres throughout the length of the wound, without any tendency to deviate.

Thus, to detach the intercostals from their attachments to the upper border of the rib, the rugine must be used from the posterior angle of the wound towards the anterior. The detachment of the intercostals below the rib is made by working antero-posteriorly for the same reason.

When this has been done, the rugine is insinuated between the inner surface of the rib and the periosteum, and the latter detached.

It is then an easy matter to divide the rib as near as possible to the extremities of the wound; this is an important detail because the divided ends should be surrounded by muscular tissue. If not protected in this way they may undergo necrosis and cause considerable trouble, or even become a source of actual danger.

Choice of Rib to be resected.— The rib to be resected will naturally vary, according to whether the empyema involves the whole of the pleural cavity, or, on the other hand, is localised.

In an empyema involving the whole pleural cavity, drainage to be effective should be placed as low as possible. From the surgical point of view, the lower border of the phrenico-costal sinus corresponds to the 10th rib at a point 12 centimetres from the middle line, which point is approximately on a vertical line

through the medial angle of the scapula. The 9th rib is therefore selected, and the incision over the rib should extend an equal distance on each side of this vertical line (with the arm lying against the body).

In the case of *localised pleurisy* or *pulmonary abscess*, the rib chosen should correspond to the lower border

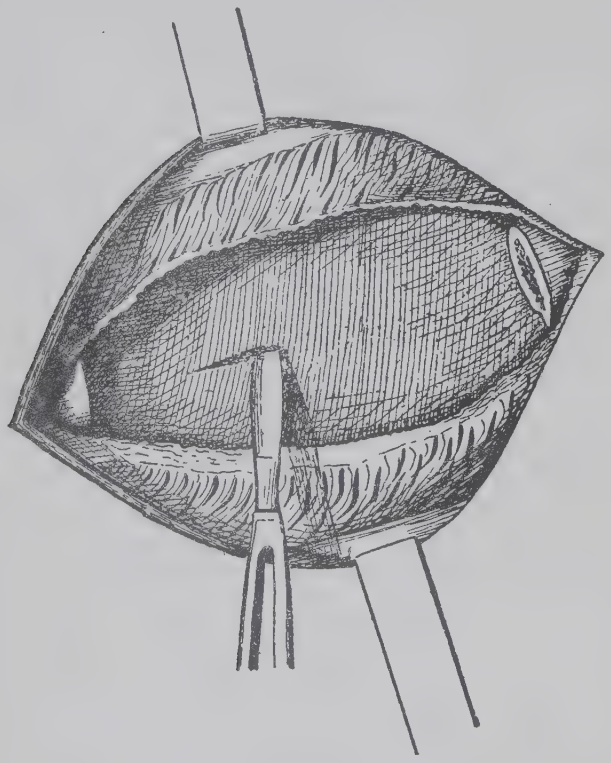


FIG. 39.

of the purulent cavity, but there will be some difficulty in locating the exact position of this point.

Percussion is not reliable. It is not exceptional, when an abscess is situated deeply in the lung, for a part of the lung to intervene between its lowest point and the chest wall, which therefore will be resonant to percussion.

Exploratory puncture is equally unreliable. It certainly indicates the presence of pus and its situation, but it is useless for determining the extent and limits of the collection.

A radiogram or screening is of greater assistance from this point of view than anything else: at the same time, the magnification and distortion of the shadow produced must be taken into account.

Decidedly the most reliable procedure for determining the situation and the lower border of the cavity is to screen the patient and aspirate with the aid of X-rays.

In this way, it is not only possible to see the downward extent of the abscess, but also to observe its depth from the surface: it may also be possible to make out whether the lung is involved, and whether there are thick pleural adhesions intervening between the chest wall and the cavity.

When the trocar is once in position under the screen, it should be left there, and if necessary used as a guide for the knife, after one or more ribs have been resected.

Moty has proposed a slightly different technique. He makes a posterior vertical incision, on the ground that the lowest point of the pleural cavity lies posteriorly. After aspiration, the rib which appears to correspond with the lowest point of the collection is resected: it is then an easy matter to prolong the incision and rib resection as far as the lowest point of the cavity, when the latter has been located by direct exploration. This procedure may be applied to encysted pleurisies as well as to those of the general cavity (Quénu).

Drainage of the Cavity.—The pus should be evacuated slowly, in order to avoid too rapid displacement of the lung, heart, and mediastinum, which might produce serious effects. Two large drainage-tubes should then be introduced. It is literally true that they cannot be too large, but they are often too long. Drainage-tubes 10 centimetres in length are quite long enough. Some surgeons, however, prefer to introduce

longer ones in order to prevent the formation of secondary adhesions which lead to the production of further collections and further rises of temperature. The tubes are shortened as the cavity becomes obliterated.

It should be borne in mind that the tubes must always be sutured to the skin-wound, or at least their disappearance into the cavity rendered impossible, by transfixing their outer ends with a safety-pin. When

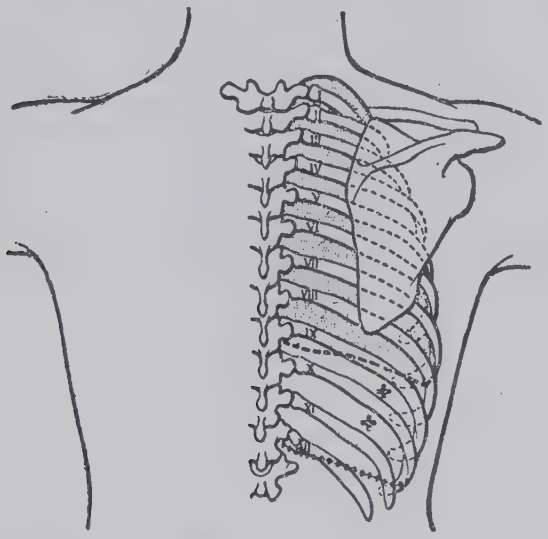


Fig. 40.

this precaution is not taken, it not infrequently happens that the tubes disappear into the cavity and keep up suppuration which only ceases when they are removed. This is such a common occurrence that it should always be suspected in a case in which suppuration persists.

The first incision, which is made by cutting down upon the trocar, may sometimes not correspond exactly with the lowest point of the abscess cavity: it is as well to realise that drainage under these conditions

will only lead to disappointment. In this case there should be no hesitation in adopting the method of *double incision*, as advised by Arrou and Silhol.

After resection of a rib, the finger is introduced, passed in a downward direction to the bottom of the cavity, and kept there as a guide. The surgeon then cuts down upon the prominence which his finger can be made to produce in the intercostal space below, without resecting another rib. This second incision is made in a moment, and does not prolong the operation to any appreciable extent.

Two, three, four, or, if necessary, even more drainage-tubes are then passed from the upper wound to the lower, and the ends tied together, to prevent their displacement. This is an effective method of drainage, and is well supported by the patient.

After-treatment.—The dressings should be renewed as often as necessary; which, at first, may be twice a day.

During the last few years, irrigation of the pleural cavity has been violently opposed on the grounds that it leads to the persistence of a sinus. We do not regard this objection as valid. Even granting that in a great number of cases irrigation is not necessary in order to reduce the amount of suppuration and lower the temperature, there is no doubt whatever that where the discharge is offensive, and the temperature high, a marked improvement may be produced by irrigating the cavity with an antiseptic solution, either permanganate of potassium, 0·25 centigramme per 1,000, or hydrogen peroxide; lately, irrigation with eusol or Dakin's solution has found much favour.

Depage and Tuffier have even succeeded in sterilising infected wounds by injections of Dakin's solution, according to the method described by Carrel, and have then completely closed them. These attempts are still too recent to be advocated as a routine procedure.

There is no need for us to insist here upon the

great care which should be taken of these patients with open suppurating chests. Nevertheless it should be borne in mind that these wounds only heal by adhesion of the two pleural layers—that is to say, by the return of the lung to contact with the chest wall. All the means which have been described for encouraging the re-expansion of the lung are justified in these cases. Respiratory exercises, regulated efforts to blow, continual aspiration through the drainage-tube so as to diminish the intra-pleural pressure, are all means

Fig. 41.—Improvised Pescher's Spirometer.

which have been proposed or described, and to which we do not consider it necessary to revert.

Results of Drainage in Empyema from a War Wound.—Suppuration of the pleura in a chest wound is a formidable condition. From the statistics to which we have referred, we conclude that in round figures two-fifths of the cases of empyema die in spite of drainage.

These figures, however, are inclusive of all cases. If, on the other hand, the date of appearance of infective phenomena be taken into account, as was

stated at the beginning of this chapter, it will be found that the mortality is greater the earlier the infection occurs.

1. If sepsis develops within a few hours, the condition rapidly becomes exceptionally grave. It is one of true septicæmia from pleuro-pulmonary gangrene. The organism and the organ attacked have no time to resist the infection. No pus forms in the pleura, which contains a greyish, putrid, gangrenous fluid. Whatever is done, the patient dies. This, at least, is our experience.

2. Usually, it is about the sixth or eighth day that exploratory puncture reveals the presence of pus in the pleura. The general phenomena are again pronounced, although not as alarming as in the previous type. The prognosis, however, is bad. Eighteen out of thirty of our cases, or rather more than half, died in spite of active and immediate treatment.

3. The prognosis after operation in cases in which suppuration appears later is quite different. It may be correctly said that in these cases alone the prognosis is favourable. Recovery is nevertheless often very slow.

The symptoms of infection slowly diminish, the temperature falls, the skin loses its earthy pallor, and the appetite returns. These cases, however, take at least two or three months to recover.

It sometimes happens that this slow recovery is interrupted, the temperature rises again and the general condition changes for the worse. It should then be definitely ascertained that drainage is being carried out at the best possible point, and that no collection of pus in still shut off in the pleura; for this purpose examination of the chest under X-rays is of the greatest utility. It should also be verified that the pleural cavity on the opposite side is not involved, and that suppurative pericarditis has not developed —a condition which we have seen several times.

II. **Treatment of Mediastinal Suppuration.**—Suppuration in the mediastinum is not common. It would seem that the fatty tissue which fills the spaces between the mediastinal organs is particularly resistant to infection. A foreign body in the mediastinum, however, may produce a localised abscess. Mauclaire has recorded a case of a deep "in-and-out" chest wound, with fracture of the sternum, in which a large retro-sternal abscess formed.

The abscess generally tends to point in an intercostal space, or to drain through the seat of fracture of the sternum. A mere superficial incision, however, does not provide for satisfactory drainage, since the abscess nearly always takes the "shirt-stud" form; it is, therefore, necessary to attack the sternum itself.

In the case of a compound comminuted or infected fracture of the sternum, the first indication is to resect the affected bone and to remove the splinters. The enlargement of the wound, necessary for this purpose, should provide sufficient outlet for the pus. In any case, it is quite a simple matter to remove the portion of bone interfering with drainage with a gouge or bone forceps, in such a way as to ensure drainage at the lowest point of the abscess cavity.

Fulfilment of this object may lead to a very extensive resection. Auvray describes a case in which a mediastinal abscess followed a septic wound of the neck, the drainage of which ultimately necessitated resection of the whole of the manubrium sterni. The patient recovered, in spite of the gravity of his general condition at the time of the operation.

III. **Treatment of Infective Lesions of the Lung.**—The treatment of pulmonary abscess due to war wounds involves no unusual technique. When the position of the abscess has been definitely located, as many ribs are resected as may be necessary to expose the cavity. The opening should be a large one, because it is not exceptional to find that the

abscess has formed around a projectile, shreds of clothing, or fragments of bone, which will have to be removed. Irrigation of the cavity must be avoided, on account of its possible communication with the air passages.

IV. **Treatment of the Parietal Wound.**—We have often remarked on the frequency of injuries of the thoracic skeleton in chest wounds; the ribs, scapula, and clavicle are often involved. We shall not discuss injuries of the spine, since their nature and gravity control the prognosis practically irrespective of the chest wound.

Fractures of the scapula and ribs are extremely common, those of the clavicle less so. These fractures are usually open and infected, and therefore contribute considerably to rendering the wound a serious one: Toussaint and Baumgartner have strongly insisted on this point. It is of the highest importance to treat these fractures, and to resect necrosed ribs and splinters of the scapula. The proximity of these infected fractures often keeps up suppuration in the pleural cavity, with which they almost invariably communicate.

Lastly, the skin wounds and the track of the projectile should be excised and carefully disinfected in these cases, as in all others. There is too often a tendency to neglect these, and to confine the attention to the deeper injury, although both are intimately connected with the course and result of the case.

PROGNOSIS

Before discussing the ultimate fate of chest cases discharged from the base hospitals, we propose taking a general view of the results obtained in the field hospitals. Statistics in the main agree, and it can safely be said that 15 to 20 per cent. of cases admitted to these hospitals die.

A general review of the total mortality resulting from chest wounds gives an appalling figure.

Now that it is possible to study statistics dealing with wounds of the pleura and lung more closely, the figures given by surgeons in previous modern wars seem astonishing. Even those who wrote at the beginning of the present war gave such reassuring figures that chest wounds would appear to be amongst the most benign of any. To-day we are far from holding this opinion.

We have already stated, although we are unable to suggest even an approximate percentage, that chest wounds are responsible for a large proportion of wounded who die on the field. Regimental surgeons estimate that wounds of the chest, together with those of the head, are the most frequent cause of immediate death on the field. We refrain from suggesting actual figures, since it would be literally impossible to prove that they were even approximately accurate.

The mortality diminishes from the aid post to the base ; this will readily be understood, since at each intermediate stage the surgeons occupied in sorting out the cases retain in their unit those most seriously injured. Many, however, never get past the first of these stages, which is the aid post. It is estimated that 25 per cent. of chest cases die at the regimental aid post before they can be evacuated.

The 75 per cent. of cases which get farther will not all get beyond the divisional ambulance to which they are conveyed.

During this journey some die, and others are retained as unfit for transport, so that at this next stage of casualty work 15 to 20 per cent. of cases are lost.

Therefore, of every 100 cases arriving at the aid post, not more than 55 to 60 will reach the field hospital.

We now propose discussing the results of treatment in these 60 per cent. of cases.

We have already seen that a further 15 to 20 per

cent. die in spite of treatment. Undoubtedly these figures are merely relative. Apart from any question of the suitability and merit of the treatment adopted, the situation of the field hospital is an important factor in determining this percentage.

The conditions of the country and the degree of activity at the front allow some surgical centres to be placed so near the front line that they are almost working under the conditions of a divisional ambulance; others are so far distant that they might almost be considered, in this connection, as base hospitals.

In order to obtain a general idea, we must therefore consider, not the results of each centre taken separately, but a total of many sets of such results.

It is quite certain, in the first place, that the mortality is especially great in the two days immediately following the admission of the cases. Pierre Duval has collated the figures given by Gatelier and Barbary, Depage and Janssen, and Maisonnet; we reproduce them here on account of their great interest.

Gatelier and Barbary, out of 20 deaths, give 7 (say a third) for the first day; 8 (another third) for the second day; 2 from the third to the eighth day; and 3 after the eighth day.

Maisonnet, out of 22 deaths, notes 11 (a half) during the first two days; none from the third to the seventh; 4 from the seventh to the tenth; and 6 after the tenth day.

Depage and Janssen, out of 59 deaths, give 30 (one-half) for the first day; 5 the second day; 4 the third day; and an average of 1 daily afterwards.

These figures are an absolute proof that it is on admission that these cases call for the closest attention of the surgeon, and we believe that, with increasing knowledge of what is required, we shall succeed in reducing the mortality of the early stages to a very marked extent.

It would seem that the surgeon is less able to be of service when sepsis supervenes. This usually occurs about the sixth or seventh day, and we believe that we are right in saying that it is the most frequent cause of death in patients who have succeeded in reaching a surgical centre.

Statistics of our cases were brought forward by G. Gross at the meeting of the *Société de Chirurgie* on February 7th, 1917. Of the 375 cases, there were 18 deaths in 48 cases of suppuration of the pleura or lung—that is to say, a mortality of rather more than 30 per cent. This condition, in our opinion, is far the commonest cause of death in chest cases who have reached a hospital.

When shock and compression of the lung by effusion have been averted, the entire efforts of the surgeon should be directed to preventing, or if necessary treating, sepsis. By realising that suppuration occurs chiefly in the pleural cavity, and that the only way of detecting the presence of pus is the use of Potain's large trocar, or the knife, rather than Pravaz's needle, we shall succeed in curing numbers of patients who are only too often treated in error for pulmonary complications. The effusion should be evacuated early, before pus-formation has taken place, and the result of such treatment will undoubtedly be a great reduction in the number of deaths from chest wounds. As a proof of our contentions, we quote here statistics of the chest cases treated by us during the later actions before Verdun, where we were in a position to receive cases direct from the dressing stations within a short time of their being wounded.

STATISTICS OF CHEST CASES TREATED AT NO. 3 MOTOR SURGICAL UNIT DURING THE ACTIONS FROM JUNE 29th TO AUGUST 15th, 1917 (49 CASES).

	Projectile.				Course.				Treatment.					Results.		
	Unknown.	Bullet.	Retained Shell-fragment.	Non-retained Shell-fragment.	Effusion.	No Effusion.	Abscess of Lung.	Purulent Pleurisy.	Aspiration.	Pleurotomy.	Thoracotomy.	Operation for Empyema.	Non-interference.	Evacuated.	Died.	Cause of Death.
	1	0	23	25	33	16	1	3	15	3	3	3	28	45	4	
Course.																
Effusion . . .	1	0	16	17	—	—	1	3	15	3	2	3	13	30	3	
No Effusion . .	0	0	7	8	—	—	0	0	—	—	1	0	15	15	1	
Abscess of Lung .	0	0	0	1	1	0	—	0	0	0	1	0	0	1	0	
Purulent Pleurisy .	0	0	2	1	3	0	0	—	0	0	0	3	0	2	1	
Treatment.																
Aspiration . .	0	0	7	8	15	—	0	0	—	3	1	0	—	14	1	Unknown
Pleurotomy [1] . .	0	0	1	2	3	—	0	0	3	—	0	0	—	3	0	
Thoracotomy . .	0	0	2	1	2	1	1	0	1	0	—	0	—	2	1	Unsuspected empyema
Operation for Empyema	0	0	2	1	3	0	0	3	0	0	0	—	—	2	1	Sepsis
Non-interference .	1	0	12	15	13	15	0	0	—	—	—	—	—	27	1	Shock ; without hæmorrhage
Results.																
Evacuated . .	1	0	20	24	—	—	—	—	—	—	—	—	—	—	—	
Died . . .	0	0	3	1	—	—	—	—	—	—	—	—	—	—	—	

1 "Pleurotomy" seems the most satisfactory English equivalent for the term here used, "*ponction élargie*," which corresponds in the text to "incision évacuatrice" or "ponction agrandie" described on p. 121 ; this consists in making a small incision to admit of the escape of *clots* together with the fluid present.—EDITOR.

PART III

LATE SEQUELÆ OF WOUNDS OF THE PLEURA AND LUNG

CHAPTER VIII

The future of men who have been wounded in the chest is a complex and difficult problem, the solution of which can only be arrived at gradually by experience. Time has already modified some opinions on this subject which had been formed too hastily.

Some patients remain in hospital for a long period, owing to prolonged suppuration, slow healing, or pleuro-pulmonary lesions; the sequelæ are obvious, although their interpretation is sometimes a matter of dispute.

Others are discharged convalescent; they are still in a weak condition, and need rest. Others seem to have recovered completely.

What ultimately happens to these men?

In connection with this subject, Hartmann quotes the opinion of Professor Estor, whose work was done in a base hospital. According to this surgeon, out of 57 cases of penetrating chest wounds, 47 rejoined their depot, 3 were transferred to auxiliary branches of the army (2 for reasons unconnected with the chest wound), 6 were discharged (3 of these for injuries of the limbs), and 1 died of pulmonary tuberculosis.

Maissonet, on the other hand, contends that very few chest cases are fit for further service in the army.

These two opinions are obviously incompatible.

Eighteen months or a year ago, it was generally

assumed that a large proportion of chest cases, who escape the dangers and complications of the first few weeks, recover rapidly and completely.

Certain facts bear out this opinion. We have recognised several of our late patients at the front, who have returned to their units three or six months after leaving hospital.

But, with a wider experience, it is being realised that, although a certain number appear to be really and permanently cured, the majority suffer from sequelæ which require medical supervision.

Denéchau, E. Sergent and Lechevallier, Belot, Ribadeau-Dumas, and Devic and Cordier have made some interesting clinical and radiographic observations in this connection, showing the importance of certain subjective phenomena, and the lesions to which they correspond. Further information is obtainable from the reports of the surgeons instructed to consider the advisability of the late removal of foreign bodies.

There is a final question of the greatest importance. What is the future of these men as regards tuberculosis ? Is not the site of an old pleuro-pulmonary wound a peculiarly favourable focus for the growth of the tubercle bacillus ?

CLINICAL STUDY

One fact is quite certain. Sequelæ in pleuro-pulmonary wounds are common.

As far back as July 1916, Denéchau, in examining fifty cases in whom the original injury dated from fifteen, eighteen, or twenty months previously, found that subjective disorders were present in every case.

These disorders, however, are extremely variable. Many are purely subjective phenomena, and it is these that usually lead old chest cases to consult a doctor ; others exhibit some more or less complex visceral disturbance, and in a certain proportion external lesions or evident pleuro-pulmonary sequelæ persist.

I. **Subjective Disorders.** — *Dyspnœa.* — This is the commonest symptom, and in exceptional cases it is permanent, being produced by any exertion. Some experience it immediately on attempting to walk faster than usual, or going up a short hill or up a few stairs may induce it; others are unaffected except by prolonged effort.

Pain.—This often accompanies dyspnœa, and is either spontaneous or induced, superficial or deep. When spontaneous it is often of a very intractable neuralgic character (Mauclaire)—intercostal neuralgia—and is usually localised in the lower part of the chest on the affected side. In other cases it is diffuse and radiates from the scar. Sometimes it is very acute, taking the form of lightning or stabbing pains. Some patients complain of a tearing internal sensation.

Pain is often produced or aggravated by cough, deep inspiration, a quick movement, walking or sneezing. When it is superficial its distribution along the course of an intercostal nerve can sometimes be defined by palpation.

Cough.—Cough is a less common symptom; it is usually dry, and comes on in violent attacks, almost like whooping-cough. When associated with pulmonary lesions it is accompanied by mucous or muco-purulent expectoration.

Hœmoptysis.—Attacks of hæmoptysis occur at extremely variable intervals, and an important fact to remember is that they are not always due to the presence of a foreign body. The quantity of blood is sometimes insignificant (E. Sergent), but the hæmoptysis may be persistent, with repeated attacks throughout a period of several months. Petit de la Villéon records a case in which slight hæmoptysis recurred during a period of seven months.

II. **Visceral Disturbances.**—Sometimes the patient complains of more complex visceral disorders.

1. In some the disturbance is chiefly cardiac,

characterised by: *precordial pain*, consisting of a localised sensation of severe distress, increased by deep inspiration, cough, or exertion; constant *dyspnœa*, increased by the slightest effort; *arhythmia* with habitual tachycardia. The instability of the pulse and respiratory rhythm, with constant dyspnœa, aggravated by the least exertion, constitute the cardinal signs of a syndrome recognised by Em. Sergent; in addition, there may be either phrenic neuralgia or Basedow's syndrome. These visceral disorders should always be looked upon as indicating a lesion of the cardiac plexus and of the phrenic nerve.

A patient under the care of Binet and Marmontel had nausea and vomiting, or even faintness and actual syncope, whenever he was made to get up. A projectile was discovered between the heart and the left lung, near the diaphragm and the phrenic nerve. These symptoms disappeared after the removal of the foreign body.

2. *Digestive Disorders* predominate in some cases; thus a patient seen by Ribadeau-Dumas complained especially of indigestion, distension after meals, severe malaise with a sensation of weight, obstinate constipation, borborygmi and belching, oppression, and tachycardia; this condition was caused by the presence of pleuro-diaphragmatic adhesions, the incidence of which we shall refer to later. Diagnosis of this condition can only be made by X-rays.

These visceral disturbances, associated with the subjective symptoms already mentioned, combine to form very varied clinical pictures.

The merit and value of recent work lies in the guidance and assistance which it may give to the practitioner in interpreting the symptoms complained of by these patients.

Sometimes nothing can be discovered to account for them. In 33 cases of old chest wounds, who were

complaining of subjective symptoms, pain, dyspnœa, etc., Ribadeau-Dumas found 4 in whom neither the physical signs nor a radiogram showed any evidence of the injury which they had received. Denéchau, in 135 cases of old chest wound, found 42 who objectively appeared to be completely cured, although they still complained of functional disturbances. Such cases, therefore, are not exceptional.

In other cases, a resulting anatomical defect, or a lesion still in process of healing, accounts for the presence and persistence of the symptoms of which the patient complains.

III. **External Lesions.**—*Parietal Scars.*—Contracted scars or extensive muscular destruction may interfere with free movement of the chest or the movements of the upper limb. These cases are rare and are always due to prolonged suppuration.

In these cases, as in others, scars remain painful for a long time, or become so again under the influence of weather changes, fatigue, or direct pressure. These painful scars may indeed prove a lasting source of trouble to the man, rendering it difficult, or even impossible, for him to carry a pack or rifle.

Some of these scars resist any mechano-therapeutic treatment. Although, sometimes, massage or ionisation may soften them, it is often found that the only satisfactory treatment is excision; and even after apparently complete removal, they may reappear in as contracted and tense a form as before.

Thoracic Deformities.—Partial muscular atrophy of the affected side of the chest need only be mentioned; it is the inevitable consequence of every pleuro-pulmonary wound, though merely a temporary and unimportant effect.

On the other hand, more serious deformities of the chest may persist as sequelæ of pleuro-pulmonary wounds; they are often confined to the base, but may be more extensive. They are associated with pleural

adhesions, and may be readily detected by means of X-rays. They play a large part in the causation of the functional disorders complained of by the patients. Denéchau, in the 135 cases on which his statistics are based, found 17 in which there was a structural change consisting either (and principally) of persistent muscular atrophy, or of thoracic asymmetry accompanied by scoliosis.

Conditions consecutive to the development of a simple hæmothorax are usually of little importance. They can in no way be compared to those resulting from the hyperplasia of the vascular connective tissue which occurs in tuberculous pleurisy.

The most marked deformities, apart from those due directly to gross injury, are almost always the result of prolonged pleural suppuration.

Scoliosis, and dense pleuro-parietal adhesions, which result in over-riding of the ribs with flattening and retraction of the lower part of the chest on the affected side, occur in these cases, as in other forms of empyema.

External examination, and palpation, will sometimes reveal the presence of callus which is causing intercostal neuralgia by nerve compression.

Sinuses.—There is little to be said about these. They are often due to a bone lesion, such as an old fracture of the ribs, sternum, or scapula. When their persistence is not due to an area of osteitis which has resulted from the injury and the exposure of the seat of a fracture to infection, they are caused by a splinter or a foreign body which remains in the chest wall, and keeps up suppuration.

These lesions are not incurable. When the focus of osteitis has been resected or scraped out, or the sequestrum or foreign body removed, there is every likelihood that the sinus will close spontaneously and permanently.

A thoracic sinus may also be the result of suppurative pleurisy. Many of this type are avoidable. If an

acute purulent pleurisy, such as a war wound will produce, is cured, a sinus should not result. When the pus has been drained sufficiently early and at the lowest possible level, and every means has been taken from the first to ensure that the lung is expanding well, adhesions form between the two pleural layers and the cavity is obliterated.

We have already seen that in some exceptional cases an abscess of the lung may point in the position of the healed parietal wound and leave a sinus. Denéchau has seen two cases of this, one of which dated back sixteen months. Mauclaire emphasised the occasional difficulty of treating these "*pneumo-cutaneous*" fistulæ. In his patient a broncho-cutaneous fistula, secondary to a chest wound, persisted in spite of several attempts to close it.

IV. **Pleural Injuries.**—Pleural lesions are very common, and play a large part in producing the after-effects complained of by these patients. They consist, as we know, of adhesions, following pleural inflammation. Pleural adhesions were recognisable in 48 out of the 135 cases in Denéchau's series. Robineau's observations on this subject are of great importance. Out of 42 thoracotomies for intrapulmonary projectiles, performed in every case at a long interval after the date of the injury, in only 9 cases were there no adhesions, in 5 cases there was a small area of adhesions in the region of the projectile, and in the 28 remaining cases they were comparatively dense and resistant, though sometimes fairly soft and easy to detach. Only dense adhesions, resulting in complete union of the two layers of the pleura over a small or extensive area, give rise to persistent trouble.

The commonest are pleuro-diaphragmatic adhesions, either partial or complete, followed in order of incidence by pleuro-parietal adhesions involving the main cavity; localised adhesions on the posterior surface and at the apex are particularly common. In 10 of

Denéchau's 48 cases, there was pachy-pleuritis at the apex.

Pleural adhesions give uncertain physical signs.

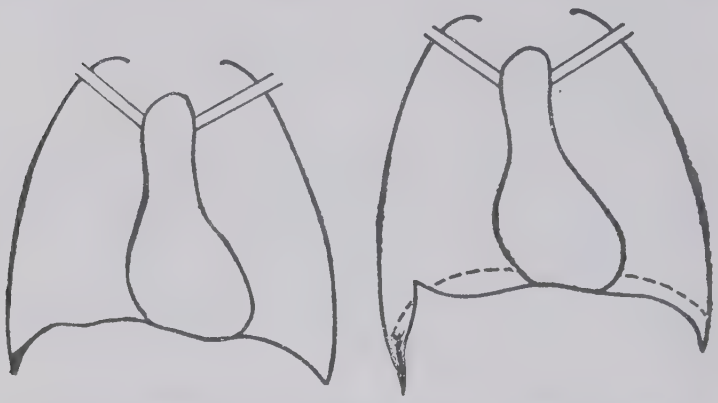


FIG. 42.—Diagram of a slight adhesion, seen at rest. The phrenico-costal sinus is somewhat blurred, and the diaphragm appears very slightly deformed with irregularity of its dome.

FIG. 43.—Diagram of the same adhesion in forced inspiration. The right cul-de-sac is scarcely open, and the diaphragmatic deformity is increased owing to traction on the diaphragm by a band of adhesions. The dotted line shows the position of the diaphragm in normal expiration.

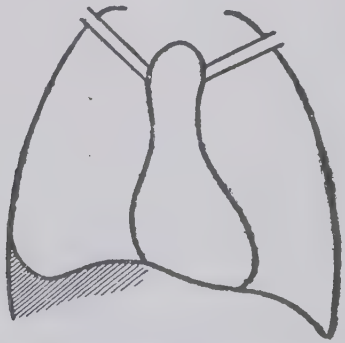


FIG. 44.—The right cul-de-sac is obliterated by adhesions, and no longer opens out in inspiration ; the sinus is filled up.

Nevertheless, deformity of the chest, absence of respiratory movement on the affected side (an important sign), some degree of impairment of note on

percussion, the absence or diminution of vocal vibrations, and diminished breath sounds, can often be detected.

A radiogram is the best means of confirming the conclusions drawn from a physical examination.

Pleural adhesions involving the main cavity give a vague shadow, which however, is more defined the more thickened the pleura. But it is particularly at the base that pleuro-diaphragmatic adhesions can be easily detected. Often limited to the lateral part of the pleura, in the region of the phrenico-costal sinus, they are recognised by the fact that the more oblique ribs with their narrow intercostal spaces are much less mobile than usual. In inspiration, the lateral sinus shows up badly, and *does not open out*; the lung, which is more or less adherent to the diaphragm, draws the lateral part of this muscle upwards, while its internal part is displaced in the opposite direction and flattened.

When the adhesions to the diaphragm are more extensive, the sinus is obliterated and invisible, the diaphragm appears thicker, and its upper limit is ill-defined; sometimes it is quite immobile and higher than on the opposite side; in other cases, its downward movement during inspiration, instead of involving the whole muscle equally, is irregular, the outline becoming angular or conical (Sergent and Lechevallier).

An X-ray examination will therefore often explain functional disturbances, which are often complex and otherwise difficult to interpret; they are the result of fibrous adhesions, which drag on and displace the mediastinum, the heart, or the diaphragm, and, through the diaphragm, involve the viscera beneath it (stomach and intestines).

At the same time it should be understood that local adhesions in the main pleural cavity may be present without being definitely visible in a radiogram. The examination may be negative, and yet during a

subsequent thoracotomy for the removal of a projectile, thickening of the pleura and even massive adhesions in the main cavity may be discovered. Robineau and Ledoux-Lebard have recorded several examples of this.

V. **Pulmonary Sequelæ.**—Various types must be considered.

These sequelæ may give rise to no functional disability, and may only be discovered during a physical examination, or even only on X-ray examination; in this category are cicatrices, properly so-called. They may, on the other hand, give rise to a group of comparatively vague symptoms whose interpretation is at times difficult.

1. In certain cases, no functional disorders are present. Belot has shown that it is possible to demonstrate the changes following the passage of a projectile through the lung. The most simple method of distinguishing a straight track is to direct the rays in such a manner that they pass through both the superficial scars. A sclerosed band or track can in this way be distinguished on the screen. E. Sergent and Lechevallier, and Ribadeau-Dumas, quote examples of this. Ledoux-Lebard has seen a number of cases in which in his opinion the radiographic shadow could be correctly interpreted as a pulmonary cicatrix due to the passage of a projectile. Devic and Cordier are less positive as to the interpretation of these shadows.

Cicatrisation is sometimes more extensive, but since it does not interfere in any way with the function of the lung, and causes no symptoms, its interest is only relative.

In other cases, X-ray examination reveals the presence of a retained projectile, which is absolutely latent, and has given rise neither to subjective disorders nor to physical signs.

2. More commonly, pulmonary sequelæ give rise

to comparatively complex symptoms, which combine to form a large variety of clinical pictures.

(*a*) In the first category, the symptoms complained of are due simply to a pulmonary lesion still in process of evolution : such a lesion is usually chronic, and the patient is likely to suffer from its effects for a long time. It generally consists of a focus of pulmonary suppuration, kept up either by a projectile or piece of cloth, or any foreign body.

(*b*) More extensive damage to the lung may be present, the process of repair being a very slow one, although, after a long period, it will be complete. Ribadeau-Dumas has described interesting examples of this in patients, whose severe pleuro-pulmonary lesions were healing satisfactorily, but were accompanied by extensive injuries to the chest wall.

(*c*) In other cases, during convalescence or even long afterwards, although the patient seems to have recovered, pulmonary complications reappear, which are usually, if not always, due to the presence of a foreign body. Sometimes the symptoms are only inflammatory, such as attacks of congestion with pyrexia, falling-off in the general health, a return of hæmoptysis and pain, etc. These congestive attacks are very apt to recur, as Eschbach and Lacaze have shown, and may reappear at remarkably long intervals.

On the other hand, the inflammation may end in suppuration. While foreign bodies such as shreds of clothing, shell fragments, splinters of bone, etc., may be tolerated without incident for a long time—and examples of this are being recorded daily—this is no proof that these foreign bodies will remain harmless indefinitely, and numerous cases show that delayed lighting-up of sepsis is always a possibility.

X-ray examination is indispensable in all these cases and affords valuable information.

PULMONARY TUBERCULOSIS AND PLEURO-PULMONARY WOUNDS

Certain pleuro-pulmonary sequelæ will inevitably suggest pleural or pulmonary tuberculosis to physicians examining cases with chest wounds received some considerable time previously. The tendency to this diagnosis is supported by almost classical beliefs in the influence of chest injuries on the development or reawakening of pleuro-pulmonary tuberculosis.

A rapid reaction from these views has fortunately occurred, and ideas on this subject are tending towards the establishment of a principle which seems to us sound. In various articles and publications, Em. Sergent first suggested that, before coming to conclusions which are so grave from every point of view, absolute proofs should be obtained, and, in the second place, that practical experience was far from agreeing with the somewhat academic theories as to the relation between traumatism and tuberculosis. The observations of Denéchau, Ribadeau-Dumas, Devic and Cordier confirm this opinion, which is fortunately being justified daily.

In the first place, research on every approved line has shown that pulmonary tuberculosis is uncommon, and even exceptional, as an immediate or remote sequela of pleuro-pulmonary wounds. This fact appears to be thoroughly and indisputably established. Such a diagnosis should therefore not be made unless sufficient evidence is forthcoming. It will be sufficient to describe the clinical phenomena which commonly appear, and which, owing to their similarity to the signs, symptoms, and effects on the general condition characteristic of tuberculosis, call for the closest investigation.

1. In the majority, as E. Sergent remarks, minor general symptoms lead to confusion between the sequelæ of chest wounds and tuberculosis. A case with an old chest wound, at the end of his period of

convalescence or at the depot, complains of cough and pain ; he loses flesh, and has a touch of fever from time to time ; in association with these symptoms, any modification whatever of the breath sounds at the apex will be held to justify the diagnosis, "bronchitis, ? Tb. Apex" ; or even more definitely "tuberculosis," with the result that the man is sent to hospital.

2. Fibrinous pleurisy at the apex (occurring in 7 per cent., according to Denéchau) may be responsible for what is observed ; and if hæmoptysis occurs at a somewhat remote date, as happened in a case of ours, one cannot help thinking of tuberculosis. And yet only very commonplace lesions are in question ; in none of the cases quoted—and they were under observation for a very long time—has the tubercle bacillus been found.

3. Cases sometimes occur in which hæmothorax has been succeeded by recurrent sero-fibrinous pleurisy. Traumatic tuberculous pleurisy is suspected, but up to the present, although a white count shows a large percentage of lymphocytes, the results of inoculating guinea-pigs have been negative, and nothing in the subsequent history of these cases during a long period seems to justify a diagnosis of tuberculous pleurisy.

4. A further possibility is exemplified by an interesting case quoted by Ribadeau-Dumas : here the persistence of pulmonary symptoms, such as febrile attacks, cough, and purulent expectoration, was complicated almost a year later by pleurisy which recurred at the end of six months.

If repeated examination fails to find the tubercle bacillus, fever and loss of flesh are not sufficient, in conjunction with the physicial signs, to justify the diagnosis of tuberculosis. As Ribadeau-Dumas remarks, the possibility of a subacute infection due to an organism of low virulence, in the region of a foreign body, which, in the case concerned, has not been removed, must be borne in mind.

These infective phenomena, which may either persist or subside only to reappear later, always attract attention, more particularly since they may react seriously on the general health. The man becomes definitely ill, with evening pyrexia, night sweats, and steady loss of flesh. These serious symptoms may be accompanied by local signs of cavitation and sometimes by hæmoptysis. It is impossible not to think of rapidly developing tuberculosis. But the majority of these cases are explained by the presence of either a foreign body, an encysted pleurisy, or an abscess of the lung.

In 100 cases, Sergent did not find one in which tuberculosis followed a pleuro-pulmonary wound.

Of 48 cases studied by Ribadeau-Dumas, only two had signs of pulmonary tuberculosis, and they were men who had had pleurisy before the war, with a family history of tuberculosis.

L. Bernard and Mantoux quite recently arrived at the same conclusions, after examining 379 cases of chest wounds. To quote their report, "Wounds of the chest have only a negligible effect on the development of tuberculosis." Of 135 cases observed by Denéchau, only three developed definite pulmonary tuberculosis, a long time afterwards ; these cases have been recorded and discussed elsewhere.

Ledoux-Lebard, who is an authority on radiography, told us that he had examined about 1,200 penetrating wounds of the chest at periods remote from the date of their injury. He is decidedly of opinion that these cases do not appear to be predisposed to tuberculosis.

The X-ray appearance indicates either localised lesions with extensive pleural thickening, or peribronchial fibrosis accompanied by enlargement of the tracheo-bronchial and mediastinal glands. It would be an error in radiological diagnosis to regard these various abnormalities as representing tuberculous lesions. Similarly the pleural lesions localised at the

apex, which are the result of hyperplasic reaction on the part of the pleura, should not be misinterpreted.

"The active cause," said E. Sergent, "in producing this so-called traumatic tuberculosis is not trauma itself, but its indirect consequences—namely, prolonged suppuration, long confinement in bed in the close atmosphere of a hospital, loss of appetite, and consequently insufficient nourishment."

Regarded in this way, any serious wound would have the same effect.

CHAPTER IX

TREATMENT

For the late sequelæ of wounds of the pleura and lung, medical treatment is required, but surgery may also be necessary.

SURGICAL TREATMENT

Indications for Operation.—Foreign bodies frequently remain in the lung or mediastinum. But, as Souligoux very pertinently inquires, "Should all such foreign bodies be removed?" or rather, "which are the ones which require removal?"

It would seem now that the surgical rule of leaving projectiles in the *mediastinum*, and of removing only those in the lung, should be abandoned.

Foreign bodies *in the mediastinum* cannot be looked upon as harmless, even when they give rise to no immediate effects. They ultimately become surrounded by scar tissue, which is sometimes soft, but often thick and resistant, and must inevitably interfere with the functioning of delicate structures in the mediastinum (Le Fort).

The indication becomes more definite if they cause trouble: cough, disordered cardiac action, and severe pain definitely indicate removal of the foreign body. The latter, owing to its size, and the fact that it moves with the diaphragm and heart, may lacerate, abrade, or ulcerate the mediastinal organs with which it is in contact.

Operation, as we shall see later, is so safe in the hands

of a skilled and experienced surgeon, that it is decidedly more dangerous to abstain than to operate.

Foreign bodies *in the lung* are equally liable to give trouble. The advisability of their removal is still, however, disputed by some surgeons. But it is incontestable, *a priori*, that the presence of a foreign body in the lung can only interfere with its function, give rise to fibrosis, and even cause ulceration of large deep vessels. A particularly interesting condition was recorded by Marion where a localised abscess around a projectile was found in two old chest cases, who complained of nothing more than slight difficulty in breathing. Robineau, in collaboration with Abt, did some work of great importance in the bacteriological examination of projectiles removed from the chest at an interval varying between six months and two years after the infliction of the injury. In two cases the projectiles were absolutely sterile. In six cases non-pathogenic staphylococci were grown, which probably were due to accidental contamination at the time of removal of the shell fragment. On seven occasions bacteriological examination showed aerobic and anaerobic organisms ; in one of these cases the projectile was bathed in pus.

These patients, even when their signs are extremely slight, usually have persistent and deep-seated thoracic pains, with dyspnœa, or rather, shallow and rapid respiration.

Mauclaire, Duval and Béclère have also observed that, under the screen, a lung containing a foreign body is seen not to move deeply with respiration, while the range of movement of the diaphragm is less extensive on the side affected.

The indication may become still more definite. The foreign body may cause repeated congestive attacks, slight and repeated hæmoptysis, and sometimes severe hæmorrhages. In one case, Walther was induced to operate to relieve a persistent " roaring " in a patient

who had a shell fragment in his lung. Singularly enough, the roaring disappeared after removal of the fragment, which suggested that it was due to a reflex paresis of the vocal cords. When a sinus communicating with the exterior is kept open, by the presence of a foreign body, it must, of course, be removed.

All these examples support the view that foreign bodies should be removed whenever possible.

But, apart from these conclusions which have been arrived at by the great majority of surgeons, we must refer to the opinions of others whose work is in the base hospitals, and who therefore see the results of these operations.

Emile Sergent and Lechevallier, in a carefully considered article on this subject, warn surgeons against a tendency to advocate the removal of all foreign bodies, whether such an operation is indicated or not.

To quote their own words, "Until the end of 1915, when the interesting communications of Mauclaire, P. Duval, and Marion appeared, it was universally admitted, not only *a priori*, but also on grounds of experience in all previous wars, that intra-pulmonary foreign bodies were better left alone. As a general rule, they were perfectly tolerated, and, should they happen to give rise to a local abscess or to gangrene, the drainage of the abscess enabled the foreign body to be removed at the same time.

"Indications for the removal of foreign bodies from the lung are, in our opinion, only exceptionally present.

"The persistence of a sinus, profuse or repeated hæmoptysis, and pulmonary abscess appear to us to be the only definite indications. The neuro-cardiac syndrome, when there is a projectile, either in the mediastinum or in the region of the hilum, may partially or entirely disappear after the removal of such a foreign body. This, however, is only a possibility, and, taking into consideration the fact that improvement or recovery may occur spontaneously, the very grave risks

involved in an operation upon the hilum or the mediastinum should be very seriously considered.

"We are convinced that the existing practice of removing all intra-pulmonary projectiles—a practice against which a reaction is already setting in (Mouchet, Mauclaire)—will eventually be discarded, because the necessity for these operations is far from being satisfactorily established, while the indications of to-day are affected by the circumstances and by the influence of war, and will cease to be of weight with the advent of peace. When the man has no longer to face the prospect of a further period in hospital and a second convalescence, he will probably refuse any operation involving any greater risk than that of the anæsthetic. Amputation cases with chest wounds, who have been discharged from the army, are already refusing operations, and it is probable that later on others will do the same."

We cannot, at present, support either side in this controversy, which will be decided by further experience. But one fact is already established,—that some foreign bodies do require removal. The extraction of foreign bodies from the chest was certainly scarcely ever attempted in cases arising from previous wars, but it should not be forgotten that a very good reason for this was the surgeons' absolute ignorance as to the situation of these projectiles, which seemed, in addition, to be well tolerated. Radiography has completely transformed this branch of surgery.

There is no doubt whatever that certain bodies may be tolerated perfectly. Lejars, at the *Société de Chirurgie*, described the case of a *médecin inspecteur* who had had a bullet in his chest since being wounded at Tonkin, and one day returned it by the mouth. Similarly, one of the authors has shown a patient who had had a revolver bullet in his chest for two years, and expelled it one day, to his great surprise, during an attack of coughing.

Whenever a foreign body in the chest causes trouble, and, *a fortiori*, if its presence gives rise to alarming symptoms, it should be detected by X-rays, and localised. Knowing its precise situation, the surgeon would be to blame who hesitated to remove it.

Operative Technique.—The large number of cases of intra-thoracic foreign body which have been observed since the beginning of the war have naturally given rise to numerous publications and discussions on the various methods for their removal.

Before any attempt is made to remove it, the projectile must be carefully localised by X-rays. Their obvious purpose is to indicate the nature, metallic or otherwise, shape, and number of the foreign bodies present, but they must also be used for determining the exact situation of the foreign body, its relation to the fixed points of the skeleton, and whether it is movable or not. Lastly, one of the various methods of measurement should be employed to determine the depth and the level of the foreign body. These investigations are required whenever removal is considered necessary, while, as we shall see later, examination under the screen may even be required during the course of the operation. The X-ray appearance may very occasionally be misleading, as by showing a shadow which is wrongly regarded as being that of a metallic foreign body. This occurred in a case of Lenormand's. Multiple shell-fragments were present, and one more pronounced shadow appeared to be that of a foreign body larger than the rest. In the course of the operation it was found to be due to the presence of a calcified gland. Michon has recorded a similar case.

A. Treatment of Foreign Bodies in the Mediastinum

In the first place, as Pierre Duval said, there is more than one way of approaching the mediastina. There is a route corresponding to each : for the anterior

mediastinum, anterior thoracotomy ; for the posterior mediastinum, posterior thoracotomy.

A. Several methods have been devised for dealing with foreign bodies in the anterior mediastinum.

All give good results, if rightly employed, for the choice of method should depend upon the situation, depth, and relations of the foreign body.

I. **Simple Intercostal Incision.** — This means of access is only applicable to superficial projectiles easy of approach. It may be often indicated for projectiles in the lung, as in numerous cases recorded by Mauclaire, but only exceptionally for a foreign body in the anterior mediastinum. Cases do occur, however, in which this simple method is adequate. Lefort was able to remove a needle from the myocardium in this way.

II. **Extensive Resection of One Rib.**—This is an excellent procedure, which is strongly advocated by Willy Meyer, Pierre Duval, Jacob, Hallopeau, and Pierre Delbet. In the opinion of Pierre Duval, " Resection of 10 cm. of a rib and ' rib-spreading ' by means of a good mechanical retractor of the Willy-Meyer or Tuffier type gives ample room : the whole hand can be introduced into the chest and manipulation is possible in all directions." The opinion of this writer, with which Le Fort agrees, is that this method is particularly suitable for foreign bodies in the region of the lower mediastinum and diaphragm. Higher up, resection of ribs, such as the second or third, gives very little room, and it is therefore better, for access to projectiles in the upper part of the mediastinum, to have recourse to the costal flap, or to sterno-cleido-costal resection.

III. **Costal Flap reflected laterally.**—This method, used by Delorme for access to the lung, is warmly advocated by Le Fort for the mediastinum. This author even believes that it would be as applicable to foreign bodies in the anterior, as it is to those in the

posterior, mediastinum. This opinion, however, has not met with universal agreement.

In the living subject, the 4th rib has been called the key of the mediastinum. "In practice, for projectiles situated high up and easy of access, the flap should be made so as to include the 2nd and 3rd ribs; for the majority of supra-cardiac projectiles, 2nd, 3rd, and 4th ribs; for projectiles in the lower half of the mediastinum, 3rd, 4th, and 5th ribs; for the diaphragmatic region, 4th, 5th, and 6th ribs. Resection of the 1st rib is useless" (Le Fort).

IV. **Sterno-cleido-costal Route.**—When the foreign body is situated in the upper part of the mediastinum, or even in the posterior mediastinum at a higher level than the root of the lung, temporary sterno-cleido-costal resection with detachment of the pleura is an excellent procedure. Pierre Duval, who first proposed and practised this method several years ago, has a high opinion of its efficacy in removing projectiles. It consists in resecting, temporarily, the inner third of the clavicle, part of the manubrium sterni, and of the first rib. This method gives remarkable freedom of access and renders any operation in the anterior mediastinum, or even in the posterior mediastinum and on the anterior surface of the spine, surprisingly easy. It is undoubtedly, however, a procedure requiring great skill, and should only be attempted by experienced surgeons.

B. The search for foreign bodies in the posterior mediastinum, in spite of Le Fort's opinion, should not always be undertaken by anterior thoracotomy. Nevertheless, in many cases, foreign bodies in very deep situations may certainly be removed by this route. Pierre Duval has succeeded in removing a fragment of shell from the anterior surface of the inferior vena cava; and Le Fort, from behind the heart.

In some cases, however, the chest must be opened posteriorly. The formation of a flap including the 8th,

9th, and 10th ribs, close to the spine, undoubtedly gives satisfactory access to the lower part of the mediastinum, but the thickness of the chest wall at this point is so great that underlying structures cannot be fully exposed. The introduction of the hand is not easy, and search for a foreign body is rendered a matter of great difficulty.

When it is a question of reaching the upper part of the posterior mediastinum, resection of the first seven ribs, or of the 2nd to the 7th, gives access to the whole of this region, but the scapula is a serious obstacle. Access through this narrow opening to the aorta, the azygos vein, and the anterior surface of the vertebral column is limited. Pierre Delbet expressed his opinion as follows: "This route does not impress me favourably. I could see nothing, and removed foreign bodies with the tip of my finger without having seen them. But I do not know of any better method of approach in these cases." Patel, who also employed this route, found it equally restricted, and even "dangerous."

All the procedures hitherto described are applicable to either side of the chest.

The choice of the side of the chest to be opened will naturally depend, in the first place, on the situation of the foreign body to be removed: when possible, however, it is better to work on the left side. Access to the deep parts is easier, and further, it is the region of the arteries, which is much less dangerous than that of the veins.

Transpleural and Extra-pleural Routes.—When the chest has been opened by the resection of a rib or the formation of a flap, a second question arises. Is it best to incise the pleura deliberately, or should this be avoided?

Some surgeons, from the fear of either infecting the wound in the course of the operation, or producing a surgical pneumothorax, have attempted

to reflect the pleura without opening it, in order to reach the foreign body.

In the operation of anterior thoracotomy, reflection of the healthy pleura is certainly an easy matter, and it is quite practicable to avoid opening it.

By the posterior route, however, it is a different matter.

The pleura is intimately adherent to the angles of the ribs and to the costo-vertebral articulations. It is also adherent to the endo-thoracic fascia, which comes away with it. The extra-pleural route is therefore narrow and the wound cannot easily be enlarged, so that the difficulties of the posterior operation, which are considerable in any case, are much enhanced by its use.

The extra-pleural method is really only indicated when there is suppuration in the region of the projectile; in all other cases, it is better to go straight through the pleura. There is no disadvantage in doing this, as M. Bazy said long ago. This is also the opinion of Pierre Delbet, and of P. Duval. Potherat wrote in reference to observations by Binet and Mesmonteil: "As far as the pleura is concerned, it should be avoided when it can be avoided, reflected without opening wherever it is detachable, and opened without hesitation when it cannot be avoided, regardless of the pneumothorax which may result if no adhesions are present. The dangers and disadvantages of surgical pneumothorax have been greatly exaggerated."

Removal of the Foreign Body.—It is usually easy to detect the foreign body by its resistance to the finger, contrasting with that of the loose tissue of the mediastinum, provided that its approximate situation and depth have been determined beforehand by X-rays.

Removal of the fragment, after locating it with the finger, is usually easy. Sometimes, however, connective tissue reacts to the presence of a foreign body, and surrounds it with a fibrous covering, which is some-

times very dense, although it can usually be divided with a probe-pointed director, and rarely requires incision with a scalpel.

Removal is not always as easy as this. The shell fragment may be concealed by adhesions, or by important organs; it may be too small to be felt easily by the finger. It is here that examination under the screen becomes indispensable. This can be done under the fluoroscope, by the method[1] of Civel and Wully-amoz, or under the ordinary screen, which is watched either by the X-ray operator, who gives directions to the surgeon, or by the surgeon himself, as in the technique of Lobligeois, Bouchacourt, Ombredanne, and Ledoux-Lebard.

Closure of the Wound.—The region of the foreign body is rarely septic, and it is still more rare to find an abscess around it; it is therefore usually advisable to close the wound completely. After all bleeding points have been secured, the flap is replaced and sutured as a whole.

It is almost impossible to suture the parietal pleura, the edges of which are torn by the needle and cannot be brought together. Air remaining in the pleural cavity will give rise to no ill effects; it is rapidly absorbed, and some of it is forced out through the wound or into the subcutaneous tissues when the patient breathes deeply.

B. Treatment of Intra-pulmonary Foreign Bodies

As in the case of projectiles in the mediastinum, X-ray localisation is indispensable from the outset. It is also a matter of no difficulty: any method is satisfactory when its use is understood, and which localises the foreign body in such a way that it can be approached by the shortest route.

[1] For details of these methods, p. 217 et seq., see *Localisation and Extraction of Projectiles*, by Ombrédanne and Ledoux-Lebard (Univ. of London Press).

(*a*) *Removal after Localisation by Compass.*—When the foreign body is superficial and appears to be situated between two ribs, a simple incision in the intercostal space is frequently sufficient (Mauclaire, Guyot, Petit de la Villéon).

It is usually necessary, however, to resort to thoracotomy with resection of a rib.

An incision is made parallel to the rib selected, and 5 to 6 centimetres of the latter are resected. The lung is then sutured to the parietes, if there are no evident adhesions to render this unnecessary.

A curved Reverdin's needle is passed sufficiently deeply through the chest wall to obtain a good hold on the pulmonary parenchyma. Three, four, or more sutures are introduced in this way round an area including the whole width of the intercostal space.

The localising needle indicates the point on the surface at which the incision should be made. The lung is freely incised so as to allow the introduction of the finger, hæmorrhage or the escape of air being disregarded (Marion).

Extraction is greatly facilitated by the fact that a foreign body, even if small and deeply situated, can be felt readily through the lung tissue. When once the foreign body has been detected, it is withdrawn with the tip of the bent finger without any regard for possible tearing of the lung, or the lung may be drawn outwards by means of Kocher's forceps, bringing the foreign body nearer to the surface, in such a way that it can readily be extracted (Marion).

Pierre Duval employs a method which involves less "working in the dark." The pleura is opened, without any preliminary suturing of the lung, and surgical pneumothorax is allowed to be produced gradually; when breathing is accommodated to this condition, the part of the lung in which the foreign body has been localised is seized with volsellum forceps and drawn out into the wound. The projectile can then be easily

palpated in the portion of lung which has been made to protrude from the wound. The lung is then incised with a scalpel over the foreign body, and the latter removed.

How is the wound in the lung to be treated ? Marion, having in view the possibility of infection, either from the lung or from the exterior, leaves the lung attached to the chest wall, and inserts a gauze drain along the incision through which the foreign body has been removed. After four or five days the gauze drain is removed and a simple dressing applied.

Duval deliberately closes the pulmonary wound, pushes the lung back, and sutures the parietal incision without any attempt at drainage, provided, of course, that there is no trace of suppuration around the projectile.

(*b*) *Removal under the Screen.*—This method has many advocates. It consists in operating for the removal of the metallic fragment, while the instrument intended for seizing it is directed by the X-ray screen. The technique varies a little with different surgeons. Ombrédanne and Ledoux-Lebard suggest that the surgeon should direct his instrument whilst the X-ray operator, who is following its course on the screen, continually informs him of the direction in which the fragment lies.

It can well be imagined that this dual control has its disadvantages. Many therefore prefer to follow the direction of their instrument themselves, either by means of a fluoroscope (" bonnette ") or on the screen (Petit de la Villéon, Mauclaire, Hallopeau).

The instrument used in attempting to reach the foreign body may be a scalpel, which cuts through the lung until it comes in contact with the fragment. A much easier method is to insert forcibly a closed pair of Kocher's or Richelot's forceps (Guyot), or to use special forceps, as proposed by Petit de la Villéon. Such an instrument passes inwards easily until it

comes into contact with the projectile. The latter is then seized and extracted without difficulty, and it might be said without pain, since Guyot has done this without an anæsthetic, through an incision previously made for thoracotomy.

Whatever the procedure employed in removing foreign bodies from the lung, all surgeons seem agreed as to the safety and ease of the operation.

It cannot be said, however, never to have produced untoward effects, and some fatalities have been published. Leriche removed a foreign body without difficulty from the lung of a man who died some hours later from collapse which could alone be explained by a cardiac reflex doubtless caused by the pneumothorax.

Two types of complication may follow this operation —hæmorrhage, and pulmonary or pleural inflammation.

Hæmorrhage into the bronchi is almost constant, but usually of no danger. Marquis nevertheless reports a case of very serious hæmoptysis.

Bleeding from the wound is rarely serious. Leriche, however, had a case in which alarming venous hæmorrhage followed the withdrawal of his finger. Marquis reports a similar case. These accidents are exceptional, and in no way contra-indicate the removal of shell fragments from the lung.

Pulmonary or pleural inflammatory complications are not so uncommon.

It is common during the period following the operation for the patient to have a slight rise of temperature, and auscultation reveals a patch of pneumonia at the point from which the foreign body has been removed. These foci may sometimes spread and involve large areas. Pierre Duval lost a case from double pneumonia after operation for removal of a shell fragment.

With regard to its effect on the pleura, it is not uncommon to find a slight reaction with effusion during the period immediately following the opera-

tion : this effusion is usually absorbed spontaneously in a few days. Mauclaire quotes numerous examples of this.

The possibility of these inflammatory pleural reactions clearly indicates the necessity of isolating the contused region surrounding the foreign body. Hence too much stress cannot be laid on the importance of isolating the part of the pleura involved in the field of operation either by suturing the lung to the chest wall by Marion's method, or by carefully suturing the incision in the lung itself, as advised by Duval.

MEDICAL TREATMENT

Medical treatment does not present any special indications.

In the first group of cases with old wounds are patients exhibiting only subjective disorders, without abnormal physical or radiological signs. A certain amount of impairment of the movements of respiration persists in many cases, in spite of any treatment. These patients should be trained to breathe, and for this purpose Pescher's spirometer (see Fig. 41), which can readily be improvised, is of the greatest value.

Slight and soft adhesions may possibly disappear eventually ; in any case, pleural adhesions, which are usually present, have a great deal to do with disorders of respiration in patients with old wounds of the chest. Here again the early employment of regular breathing exercises will be found very useful.

With regard to patients exhibiting the various types of inflammatory reaction which we have described, it is well known that in the great majority of cases these conditions are kept up or lighted up again by the presence of a foreign body, often a projectile or a piece of clothing. Sometimes, however, as in numerous cases which have been described, no foreign body is present. It seems that in the long-run these pulmonary sequelæ gradually disappear, although they

may persist for a very long time. It is therefore important to keep the patient in the best possible hospital conditions, in order to provide him with plenty of fresh air and to avoid any contact with infection. We have pointed out the importance of avoiding an ill-considered diagnosis of tuberculosis, however suggestive of it appearances may be, and need hardly insist again upon the need for avoiding the promiscuous methods of tuberculosis officers in these cases.

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